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CREATIVE ENGINEERING



DESIGN comes first in the familiar trinity of functions that define the field of chemical engineering. Construction follows; then Operation carries on. But of the three, Design is the really creative function of the chemical engineer. Because it starts at the very beginning of the machine, or the process, or the plant,

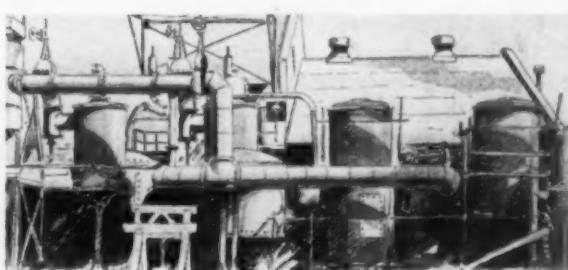
chemical engineering design underlies practically all industrial progress. So it is that, in today's crisis, industry turns to the chemical engineer for the basic idea, the new viewpoint, the scientific method of attacking the crucial problems of present-day production and distribution. His is a most unusual opportunity.

The design function of the chemical engineer has lately found profitable expression in a wide variety of new processes and products. It is as if the depression had placed a premium on novelty in purpose and performance. Engineering staffs have been increased and their energies concentrated on improvements to lower costs or otherwise open markets that were inaccessible to the older machines or materials. As an actual demonstration of the extent and character of this accelerated progress, the forthcoming Exposition of Chemical

Industries promises to be one of unusually timely interest and value.

Another perspective of these advances in chemical engineering design and construction is to be had in this Thirteenth Chemical Exposition Number of *Chem. & Met.* Here a group of distinguished contributors deal with the design function, first in its broadest conception as it affects all the work of the engineer, then in its industrial aspects as the accumulated result of many improvements in manufacturing processes, and, finally, in its specific application to the unit operations and the equipment through which they are applied in industry. All elements in this program converge in a single purpose: to encourage the chemical engineer to greater accomplishment—to urge him to draw more deeply on his latent resources of science and experience.

His grounding in the fundamental sciences of chemistry, physics, and mathematics is, after all, the chemical engineer's greatest specific asset. It gives him adaptability lacking in the older professions. It provides a logical approach to the problems of any business—a working procedure for applying new knowledge and principles to industrial practice. More and more this creative function has become a determining characteristic of the chemical engineer. Today it offers him his greatest opportunity in laying out and carrying through the plans for rebuilding industrial prosperity.



EDITORIAL



THE PLACE OF THE EXPOSITION IN CHEMICAL ENGINEERING

Is the National Exposition of Chemical Industries merely a marketing place for equipment and supplies? Is it just another means of bringing buyer and seller together to talk and barter over products and processes? Frankly, we think it is not. We regard the Exposition as an institution, built upon a history of brilliant achievements on behalf of the American chemical industry and profession. And, because these intangible attributes are too often taken for granted or lost sight of entirely in the more immediate commercial interest, it is perhaps worth while to take a brief look back over the record of the past, in order to appreciate the development of the present as well as the trend of the future.

The idea of the Exposition was conceived in the library of the Chemists' Club in New York just a few months after the outbreak of the war in Europe. Those were busy times. Two young American chemists, who were serving in the evenings as volunteer librarians, unwittingly found themselves a consulting bureau of information, since much of their work consisted in locating sources of sorely needed apparatus and equipment for chemical manufacture. The war had cut off the supply from abroad, but every day new American equipment manufacturers were springing up. So, for their own convenience, these chemists catalogued the names of firms that could supply chemical-engineering equipment, and as their lists grew, they began to think of the good that might be accomplished if these manufacturers could be brought together and their interests fused in the common purpose of developing an American chemical indus-

try. Charles F. Roth, then chief chemist of the Standard Oil Company of New York, originator of the idea of the Exposition, soon interested the manager of the International Exposition Company at the Grand Central Palace, who immediately recognized the possibilities of the plan.

But, unfortunately, there was not the same enthusiasm among the older members of the profession. The chemical industries were too secretive, too self-centered and individualistic to appreciate the value of any joint effort with the equipment manufacturers. The chemical societies and associations, even the Chemists' Club, refused to sponsor the movement, despite the promise of profit, reinforced by a waiver of responsibility in case of deficit. Finally, however, the members of a small group of prominent chemists were persuaded to join with the enterprise and serve as the first advisory committee. In this number were Raymond F. Bacon, director of Mellon Institute; Charles H. Herty, president of the American Chemical Society; Arthur D. Little, president, Arthur D. Little, Inc.; Henry B. Faber, Industrial Filtration Corporation; Bernhard C. Hesse, chemist, General Chemical Company; R. P. Perry, vice-president of the Barrett Company; T. B. Wagner, Corn Products Refining Company, E. F. Roeber, editor of *Metallurgical*

& Chemical Engineering; George D. Rosengarten, president of the American Institute of Chemical Engineers; Col. William Cooper Proctor, and Utley Wedge. The names of Dr. L. H. Baekeland and M. C. Whitaker, then president of the Chemists' Club, were not included in the official roll of the first committee, although they gave their whole-hearted support and have since been active on all succeeding committees. Likewise, five others of the original list still serve the Exposition in this advisory capacity.

The first exposition opened the doors of the Grand Central Palace, Sept. 20, 1915. There were 83 exhibitors, and during the week 63,000 visitors came to assure the success of the venture. A year later a second floor was required to accommodate the 188 exhibitors, and attendance had mounted to 80,000. The third exposition, coming after we had entered the war, registered new high points in patronage and exhibitors, for 97,000 visited the 288 exhibits that year. And so it went; each larger than its predecessor until the peak was reached at the sixth, in 1920, with 437 exhibitors and 126,317 attendance.

Then a change came over the Exposition, and to explain it we must go back over the situation that existed in the trying days of 1915 and 1916. American chemists generally were in bad repute. The layman, and the banker as well, had little confidence in our ability to build a chemical industry in this country. Education of the general public was sorely needed and the Exposition proved to be a most effective agency for that purpose. Thus, in addition to developing solidarity and cohesion

among the diverse interests of the new industry, it afforded an opportunity to dramatize the astonishing progress being made in American dyes, pharmaceuticals, and other synthetic, organic chemicals. It was this that attracted great popular interest and led to crowds that taxed the capacity of the Palace as well as the patience and courage of the exhibitors. A change in policy obviously was necessary, so the management, in concert with the exhibitors, began to limit attendance to those more directly interested in chemical industry and at the same time encouraged technical sessions, joint conventions, and other means of attracting chemists and engineers from related industries.

A cognate field in which special interest soon developed was that of power generation and use. A Fuel Economy Section of the Chemical Exposition became the nucleus from which was developed, in 1922, the first National Exposition of Power and Mechanical Engineering. Almost from the start the Technical Association of the Pulp and Paper Industry was also intimately connected with the Chemical Exposition, and in April, 1923, this interest was capitalized in the Paper Industries Exposition. Thus, as in other activities, chemical industry led the way for other developments.

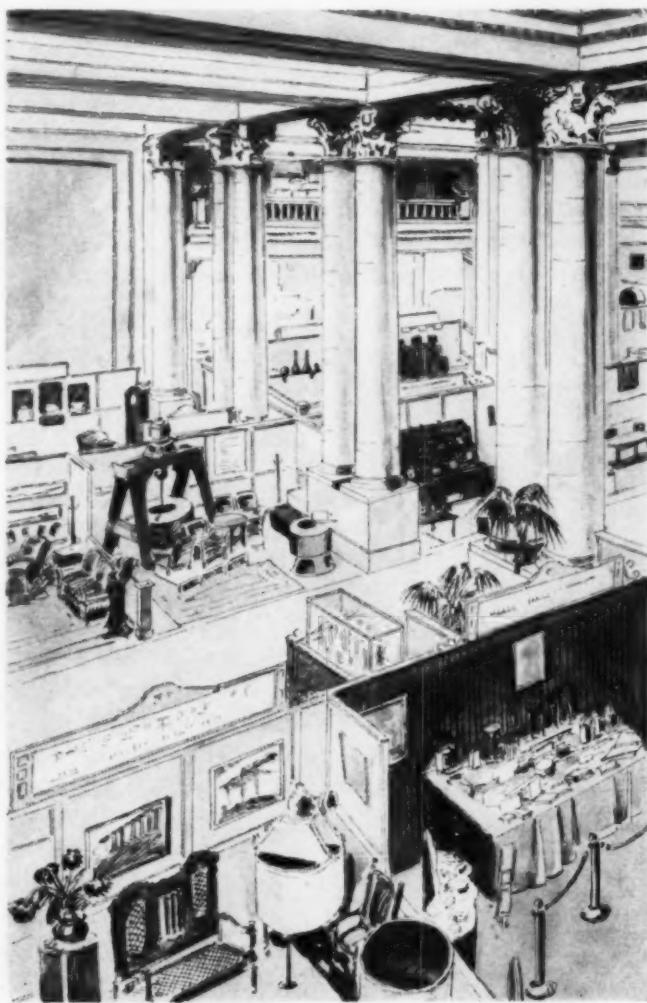
In keeping with the early history of the exposition, its managers held to the view that it should be exclusively American. Through 1917 and 1918 they had worked unstintingly in mobilizing chemical industry in the interest of national defense. The equipment and machinery for the creation of war supplies played an important part in our military program. Only naturally it was many years—1925 in fact—before foreign exhibitors were invited to participate in the Exposition. Today a policy of narrow nationalism seems short-sighted, yet at that time our chemical independence was the most important consideration and the Chemical Exposition served a real purpose in promoting this worthy cause.

Closely allied in the work for the national defense was the early attention given to the development of natural resources, more particularly the chemical raw materials of the South. A Southern Section was first organized in 1916, and so closely did it identify chemical industry with the South that in April, 1918, President Wilson personally authorized the use of a special train for conveying a party of electrochemists and engineers on a complete tour and inspection of Muscle Shoals and other Southern chemical developments. The tour was sponsored by the

American Electrochemical Society with Mr. Roth in charge of arrangements.

Interest in the growth of the industrial South continued after the war, but so, too, did the original purpose of encouraging American research and development. Thus at the Tenth Exposition in 1925, the Advisory Committee arranged with the American Chemical Society to hold a "Court of Chemical Achievement" as a means of presenting to the profession and the public the significantly important advances in the science and its industrial application. More than thirty achievements, ranging from Prof. W. D. Harkins' separation of the isotopes of chlorine and mercury to Victor Hybinette's temperature-resisting alloys, were cited by the committee of judges under the chairmanship of Prof. Marston T. Bogert.

From the very beginning the direct educational value of the exhibits was recognized, but for the first few years there were no organized student courses. Since 1920, however, Prof. W. T. Read, then at Yale, had included a week at the exposition as a regular part of an inspection trip which was a required course in the chemical engineering curriculum. Believing that this successful experience should be more generally applied, the editor of *Chem. & Met.* in November, 1922, strongly urged the establishment of a student course under the Exposition management. The suggestion was accepted almost immediately, and the first course was held in 1923 with Professor Read in charge. In each Exposition since that time, more than 100 students have registered to take advantage of this unusual opportunity for instruction, while as many as 300 have attended the lectures. And scores of leading engineers and prominent industrialists have served in Professor Read's volunteer corps of lecturers and instructors.



THIS much of the history of the Exposition of Chemical Industries has been cited to show that it has been a great and powerful force in shaping the development of chemical engineering. Today, more than ever before, it is a useful co-ordinated agency for bringing the engineer into close working touch with the many new machines and materials that can increase efficiency and reduce costs. It gives him the opportunity actually to see and compare competitive products, in order to select the particular type of equipment that best meets the exacting requirements of modern production. In the past sixteen years, it has become an inseparable part of the profession and practice of chemical engineering in America.

PLANS AND SPECIFICATIONS FOR AN ISSUE OF CHEM. & MET. ON CHEMICAL ENGINEERING DESIGN AND CONSTRUCTION

Being an animated flow diagram of mental processes in the editorial sanctum as this issue was planned

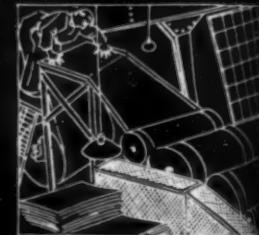
The Problem



Mister Average Reader—whatever he is. Idea! Design an issue? Why not an Issue on Design? Chemical Engineering Design and Construction! It would be hard to find a subject closer to the theme of the Chemical Exposition or more nearly in line with the needs of every chemical engineer. And so, that will be that



The first step in the solution of a problem is, tritely enough, the definition of the problem. In this case the definition is easy to find: "To Design a Pre-Chemical Show Issue of Chem. & Met.," to make it appropriate to the occasion, to make it interesting and useful to that dear friend and severest critic—



What is the first step after the problem is defined? It sounds pretty foolish in cold type, but the next thing to be done is to discover how the problem can be solved. What are the tools a chemical

engineer has at his disposal? Where can he go for information that is not at his finger tips? He can't know it all. He needs answers to these questions. We certainly want such an article



After the laboratory, what? We can't take a new process directly to the plant without watching it in semi-works equipment first. Even then, there will be more than a plenty of "bugs" to get rid of when we start up the full-scale plant. What does the development engineer think about this? How does he go about translating the results of beakers and balances and burettes into a money-making process? This is a subject on which volumes could be written.



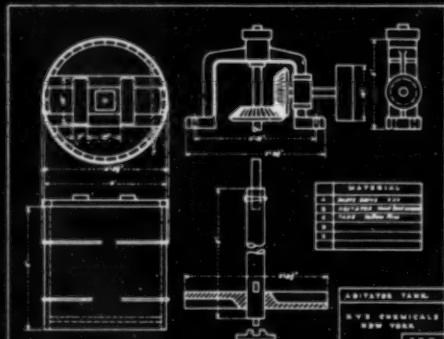
Then, when our process is perfect, we have to house it. Expensive equipment, or most of it at least, has to be under a roof, not only for its own protection but to provide adequate shelter for the personnel. What should the building be like? Single- or multi-story? Windows or no windows? This should have an article



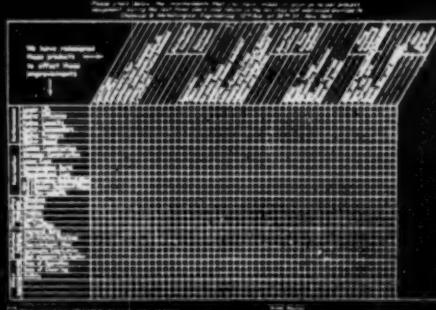


There now; we have examined the process and we know how to choose a suitable building. Equipment—perhaps thousands of dollars worth—has to be purchased or, if just what we want cannot be bought—designed and fabricated. This is a very excellent opportunity to throw away a lot of money should the design be wrong or the construction be faulty. Are new designs or redesigns justified? What is the real cost of a piece of apparatus? Is material choice governed in any way by economics? Weld or rivet? Liners or solid metal? Standard or special? These subjects need three articles

But before we go too far into the business of building a process and a plant from the ground up, it would be valuable to see how someone else has done it. Some of the most remarkable examples are to be found in the synthetic solvents industry. We'll include an article tracing the design features in the evolution of one unique member of that industry. And while we are thinking of industries, we should work up a symposium on recent design in the other process fields



Which brings us down to the fundamentals of chemical engineering, i.e., the unit operations. Not all can be taken up at adequate length from the standpoint of design, but mechanical separation, distillation, evaporation, grinding, drying, absorption and adsorption, and mixing should be a good cross section. Then several allied subjects such as power services, high-pressure design and control should be discussed



And now the home stretch! Where is chemical engineering design headed? What improvements are being made now? Which have been made in the last few years? This is a chance to send out a thousand or so of those questionnaires so dear to the heart of The Editor. We'll try to boil down the things the equipment makers have been doing, and when that is done—if articles could only edit themselves—well, we'd be in conference . . .



TOOLS FOR THE ENGINEER IN THE DESIGN OF CHEMICAL PLANTS

By CROSBY FIELD

Engineer, Brooklyn, N. Y.

◆ THE PRIMARY FUNCTION OF ANY PIECE of chemical equipment is the handling of certain materials during one or more changes in chemical or physical state, together with the regulated supply of other secondary materials which induce (or increase), arrest (or decrease), or otherwise control the rate of these changes in state. The secondary or controlling materials most frequently met with are the media for heat transfer, such as steam or electricity.

The difference between handling in a batch and a continuous process is largely a matter of whether the materials undergoing reaction or these secondary materials are physically transported in a progressive and regulatory fashion during the reaction. In other words, in the batch method, the raw materials are placed simultaneously or successively in a container of some sort, the secondary materials supplied in a controlled fashion so that different zones of conditions are successively maintained therein. In the continuous process, these zones are maintained in different pieces of equipment or different parts of the same equipment, and the materials are progressively transported from one zone to the other.

(The controlling factor in the selection between the batch and the continuous process is, in the last analysis, merely a matter of volume of production. From rolling mill to complex coal-tar product, the designer may rest assured that when the volume grows large enough, a continuous process will be devised. If, therefore, at the present time the technique is not sufficiently well established to insure the success of a continuous process, the batch must be used, but should be adopted with the idea of its relative speedy abandonment in favor of the imminent continuous process.)

IN ORDER TO DESIGN EQUIPMENT THAT will handle properly these materials, the first knowledge to be obtained is a thorough understanding of the chemical and physical characteristics of the materials entering the reaction, and the products resulting. Not only is it necessary to know their characteristics at the beginning and at the end of the reaction (which is fairly easy to ascertain) but also all during the reaction and, further, the effect of reasonable variation in the quantities of primary and secondary products in the characteristics of the combined mass, as they vary from moment to moment and from one part of the mass to another. The establishments of the necessary limits in these characteristics and their control within these limits is one of the fine points of design.

The start of the necessary studies to obtain these data, of course, is the chemical laboratory (Tool No. 1), but



Crosby Field is unusually equipped to describe the useful tools which, in the service of experience, produce effectual design. For two years he was consulting engineer under Dr. C. P. Steinmetz at the General Electric Company and for six years he was chief engineer of the National Aniline & Chemical Company. During the war, he held authoritative posts for the Ordnance Department both here and abroad. Since that time, his capability has been asserted in numerous fields where design of operating equipment is a decisive factor; thus he is now president of the Flaklee Corporation, president of the Chemical Machinery Corporation, and vice-president Brillo Manufacturing Company.

the results obtained here should be considered as merely indicative, and before acceptance they must be checked by the most useful tool in the chemical engineer's kit, the pilot plant (Tool No. 2). The importance of this step cannot be overemphasized; unfortunate indeed is the process that must be attempted on merely the results of Tool No. 1. Nevertheless, there are times when it must be attempted, just as there usually will be one or more of the engineer's tools missing, which must be compensated for by the experience of the engineer. The pilot plant alone will frequently compensate for the lack of most of the other tools. In addition to its other functions, it is the materials testing laboratory of the mechanical engineer, without the results obtained in which, no mechanical engineer today would dare function.

All of the above characteristics must be considered from the viewpoint of the materials handling side of the problem. What are the temperature, concentration, or fineness limits within which the mass may be handled in available equipment without balling up, cementing, decomposing, burning, or one of the many other accidents that will lower production or put the equip-

ment temporarily or permanently out of commission?

The next tool is the flow diagram (Tool No. 3). This should first be laid out in the most general terms possible, and resolved into terms of dollars and cents of installation and operating cost for each step. In applying the flow diagram the controlling factor of economics takes command, and various alternatives promising a chance of cost reduction may have to be proved feasible by again using Tools 1 and 2. Yields at each step are a matter of cost, and loss in theoretical resultant products should be entered as a charge against that step of the process, including not only the cost of the raw materials entering but also all elements of "fabrication" cost up to and including that step.

One of the most common errors in thought in studying the flow diagram is too fine a subdivision of the process, considering a succession of unit processes instead of the handling of the material from the beginning to the end of the chain. Thus the flow diagram may seem to require settling, filtering, and drying. These three steps should be considered as one: deliquescence (dewatering). One piece of equipment may perform the entire task, or if not, the subdivision of the amount of dewatering between filtering and drying will be found normally to be better selected by a comparison of the relative cost of mechanical dewatering as compared with the cost of heat—normally greater, but frequently obtainable as by-product and almost free.

HAVING ALL INFORMATION NECESSARY from application of Tools 1, 2 and 3, we now enter on the selection of the final unit processes, and resulting equipment, that are to determine the engineer's success or failure. Where his knowledge of unit processes as applied to the material is complete, because of his previous experience, he takes little risk, but, unfortunately, our constantly increasing rate of development in the chemical industries is so great that any man who relies only upon the application of his own experience is certain to be left behind, so recourse must be had to other data.

In the mechanical or electrical industries the starting point for the acquisition of this information is the handbook (Tool No. 4). Although we have a number of most excellent chemical handbooks, we have no chemical engineering handbook containing sufficient information regarding unit operations and equipment to enable us to use it. To be effective, such a handbook should contain not only a description of the operation and the embodiment of it in the finished equipment but also detailed data as to the various materials to which it has been applied, the power and other services required, and the approximate installation and operating cost. A comparison, for example, of the information given under "Pumps" in a mechanical handbook and that given under "Nitrators" in a chemical engineering handbook will speedily illustrate the difference. Nevertheless, this tool must some day be created, so we may designate it as Tool No. 4.

The chemical engineering handbook is the first reference so far for information of a general nature that might be applicable to the process in hand, as it is obvious that the chemical laboratory, the pilot plant, and the flow diagram, although requiring a great deal of experience behind them, are specific. In lieu of the chemical engineering handbook a number of sources of general information are called upon not only to perform their own rightful functions but also to compensate for

the lack of it. These most useful tools are: the chemical engineering periodical (Tool No. 5), the publications of chemical and chemical engineering societies (Tool No. 6), chemical engineering textbooks (Tool No. 7), chemical equipment manufacturers' catalogs (Tool No. 8), the bulletins of manufacturers of chemicals (Tool No. 9), bulletins of the manufacturers of special materials and metals (Tool No. 10), and the publications of government and university laboratories (Tool No. 11).

The use of these tools is obvious, yet it should be pointed out that the rapid advances in our chemical industry have placed it in a situation where the designer must keep up with the very latest data which may in any way become useful to him not only in the present problem but also in any likely future work in his line. In particular the periodical devoted to his branch of engineering is in a position to bring him the latest practical results of experimental designs in other lines.

In applying the data obtained from these general sources of information, a few words of caution are necessary. The first class of data is that dealing with heat transfer. The work of our chemical engineers on heat transfer recently has been ably accomplished and momentous in value. In their achievement not only the chemical engineers but all branches of engineering have profited, and it is not too much to say that within the past decade our entire design of heat-transfer surfaces has been revolutionized by the data thus obtained, and published in Tools Nos. 5, 6 and 7. In applying these data, however, either the accurate results in the pilot-plant tests must be used or large allowance be made for ignorance of unknown factors. Again, the manufacturers of special materials in their bulletin make every effort to give accurate information, but the results of corrosion in the laboratories using pure acids and alkalis is a far different matter from the varied changes in chemicals taking place during a reaction, not to mention presence of impurities and unknown conditions.

Another group of tools which should be assiduously cultivated for general information, but rarely rendering available specific data to aid in solving a particular problem, comprises visits to process plants (Tool No. 12) and expositions and other demonstrations (Tool No. 13). It is indeed rare that opportunity affords visits to plants making the same products, but there are elements of similarity in most plants that are of considerable value. The exposition is of value principally in its opportunity to study the latest mechanical equipment.

A tool (No. 14) which can be of great value and yet is frequently the most dangerous is the equipment manufacturer's demonstration laboratory. The danger lies principally in the attempt to use it instead of your own pilot plant. It would be much safer if the miniature equipment could be transported from the manufacturer's laboratory to your own private plant, used, and returned.

THE LAST TOOL TO BE SPECIFICALLY mentioned is the engineer's experience. It should be applied last, but is most important. Attempts have been made to publish certain standardized specifications for mechanical equipment, but the writer is not aware of its having yet been done in a general fashion for many types of chemical equipment, so it is still the fundamental job of the engineer to make his own check list (Tool No. 15). This should contain details of the specifications, and in particular should have underscored the obvious details most frequently omitted. Among the most fre-

Professional Equipment of a Designing Engineer

Tools in the Kitbag of Experience

Tools of Specific Application to Problem

1. Chemical Laboratory
2. Pilot Plant
3. Flow Diagram

Tools of General Application

4. Chemical Engineering Handbook
5. Chemical Engineering Periodicals
6. Publications of Chemical and Engineering Societies
7. Chemical Engineering Textbooks
8. Catalogs of Equipment Manufacturers
9. Bulletins of Chemical Manufacturers
10. Bulletins of Companies Selling Special Construction Materials
11. Publications of Government Bureaus and University Laboratories
12. Plant Visits
13. Expositions and Other Demonstrations

For Checking Selection of Type of Equipment

14. Laboratories of Equipment Manufacturers
15. The Engineer's Own Check List

quent offenders by their absence are: Horsepower required? Size of feed pipe? Kind and size of product outlet? Outlet and inlet openings for each service? Steam? Water? Air? Air Pressure? Refrigeration? Wearing or corroding parts accessible and easily replaced? If material is very valuable, how caught in case of break in equipment? Etc., etc., etc.?

Remembering the definition of chemical equipment given at the beginning, it naturally follows that the limits of design are soon reached and progress in design therefore ceases until new materials having characteristics that extend these limits become available. The chemical engineer, therefore, owes it as a fundamental of his profession to keep in close contact with the development of all new materials, and in so doing it will be noted that he must perforce maintain close contact with the metallurgist.

All of his tools must be used with keen judgment. It is rare indeed that an engineer makes an error of commission; that is, makes a mistake in a detail of design which he should not have made in the light of his experience. The most frequent errors are those of omission, where some vital factor not previously met in the engineer's experience steps in and invalidates a design which otherwise would have proved very meritorious. Experience, especially the broadening kind in fields other than the particular one containing the problem on which the engineer is at the moment working, is the only shield against such dangers.

A frequent source of error in design is the endeavor to make a single piece of equipment perform all manner of functions. The result is simply a compromise that performs nothing satisfactorily. This frequently finds itself in the failure to differentiate properly between storage and manufacturing functions in the same piece of equipment. At first glance it seems to be proper to install, let us say, a nitrator, use it for nitrating for a

brief fraction of the 24 hours, and then let our material stand in it for the rest of the period. Not only could tanks be obtained for storage at very much less cost but they can generally be found much more satisfactory in the actual handling of the materials, and the repairs on them are negligible in comparison with those on a manufacturing piece of equipment.

An actual example of the use of these tools would be interesting, but, unfortunately, neither the space available nor the nature of the data will permit inclusion here. In general, however, the procedure will be something as follows:

From the viewpoint of this article it is of little consequence whether the chemist has discovered a new product and has requested the sales department to sell it, or the sales department has found a demand for the product and requested the chemical department to develop it. Our starting point from the viewpoint of plant design is having a product worked out in the chemical laboratory and the acknowledgment of the potential or actual demand for the product.

FIRST, A BRIEF WRITE-UP OF THE PROCESS and a sample of the product, with an estimate of consumption, is laid before the engineer. He then figures the economical size of production plant and proceeds with the chemist to follow through a complete batch in the laboratory, in order that the materials of construction for the pilot plant may be determined. In following this batch through, which, of course, will be done in the usual containers of glass and porcelain, a study should be made throughout the entire operation of the chemical and physical properties of the material. Another batch should be run in the same equipment, but arrangements made to introduce into each of the pieces of equipment a sample of the material that it is proposed to use in the finished plant equipment.

After the batch has been produced, not only should these samples be examined and weighed for corrosion loss but also the material itself should be examined closely to see whether or not the presence of any of these proposed materials of construction have affected it. The engineer and the chemist having determined these points satisfactorily, the pilot plant should be built, which is, of course, a miniature of the finished plant containing vessels that will hold batches of from 10 to 30 gal. In certain cases where it is desired to test the market, the pilot plant can be made slightly larger, and it then becomes in reality a small production unit.

It must be emphasized, in designing and constructing this pilot plant, that no equipment be used that is not a true miniature of the proposed finished plant. Although the very careful work in the chemical laboratory above mentioned should preclude any difficulty with the product from the pilot plant, it will generally be found that the materials of construction have affected the pilot plant product, and recourse must again be had to the laboratory to determine the location of the offending material, to isolate it, and then either eliminate it or treat the finished product because of it.

Frequent changes in the pilot plant will be necessary. Speeds of agitation, heat transfer, and other physical constants should be obtained and compared with those published. Attempts to combine steps in the flow diagram should be made. Too much care in this phase of the development cannot be taken. The crucial stage for the chemist is in the laboratory; the crucial stage for the engineer is in the pilot plant.

PROCESS DEVELOPMENT OFFERS OPPORTUNITIES FOR INGENUITY

By CHARLES R. DOWNS

*Weiss & Downs, Inc.
New York City*



◆ A NEW PRODUCT IS BROUGHT TO THE attention of a prospective manufacturer. The manufacturer may already be engaged in the production of products based upon the science of chemistry. In other cases, the production process may be offered to an investment banker for underwriting a new corporation, to a group of men who have been successful in other lines of business activity, or to an advertising house that is in search of new products for present or prospective clients. The product may be an entirely new material. It may be that it is not produced in this country but is in production abroad. The manufacturer of chemical products may have hit upon this new product through his own research laboratory in an attempt to diversify his line, either as a further outlet for his regular products, as a profitable means for the disposal of byproducts which he has discarded as of no value in the past, or, as sometimes happens, an entirely new venture somewhat unrelated to his past activities. Again, the process may be brought to the chemical manufacturer from an outside source. Prospective manufacturers who are not already engaged in producing chemicals or unrelated fabricated materials generally do not develop such products themselves and, hence, they are brought to their attention from independent sources in a more or less finished stage of technical development.

If the product is already being produced and the process details are known either to the prospective manufacturer or to reputable consultants who can design the plant, put it in operation on American raw materials, and predict costs, there is little or no chemical engineering development work required. Here the production is a matter of direct competition of standardized procedure with more or less written-off competitive plants. If the process is in successful operation abroad, it may well be that the process is not transferable, without modification, to this country, because of the amount of labor required, the availability of suitable raw materials, the credit obtainable for byproducts, and other economic factors.

We will assume that these factors of production are known and that a market for the product exists or can be developed. The process may be described in the literature in considerable detail. It may even be communicated in extensive detail by the foreign producer, but in the majority of cases it is better to investigate it before exec-

Graduating from Yale University in 1912, Dr. Downs began a career that has given him a broad experience in the development problems of the process industries. On leaving college he followed his early interest in coal-tar technology and became associated with the Barrett Company, first as assistant and later as chief chemist. He left this position in 1922 to join the National Aniline & Chemical Company, where he was in charge of development work, resigning in 1923 to become a partner in the firm of Weiss & Downs, consulting chemical engineers.

tion here. This is especially true if there is more than one possible modification of the process to determine the one most suitable for American conditions. The proposed product and the numerous modifications of the process should then be studied from an economic standpoint, considering markets and necessary quality of the product. Possible price reductions of the identical material by domestic or foreign producers; competition by other products used for a similar purpose; and new products "in the wind" that may compete should also be investigated. Geographical location of the plant in respect to markets, including those for the byproducts, should be considered, as well as commodity rates affecting geographical location; supply of raw materials, including likely price fluctuations in the future; credits for byproducts; tariff protection; patent protection; estimated investment in plant plus working capital and calculated material; labor; and overhead charges.

If the process is still in the laboratory stage, the determination of the above factors can be little more than an intelligent guess based upon broad experience in the operation of similar processes. If a conservative calculation of the cost of production appears to promise only a thin margin of profit, visualizing reduced profit from competing materials, the possibility of manufacture should be dropped as too speculative. If, however, the profit offers real attraction, the next step is to check these factors by more laboratory work, followed by pilot-plant design and operation.

Add to the above complicated picture the possibility

of several manufacturers installing plants, each one to produce the entire requirements of the United States. This is a point that must be emphasized, as it has happened too often already with new developments, and regardless of the technical efficiency of the plants, all producers suffer. Generally the company with insufficient capital, improperly located plant, or weak management will be the first to fail. Even with a single manufacturer the capital requirement to see the thing through must be ample. If not, the measles, mumps, and whooping-cough period may weaken the infant to such an extent that transfusion of new blood puts the patient in the hands of the receiver.

A statement of the proper procedure sounds like a trite commonplace, but there have been numberless examples of processes that were taken from the paper stage to large-scale production, resulting in expensive failures. Examples of these can be cited in large corporations. They are not limited to novices, although they suffer more often. Qualified men with wide, successful experience in making such surveys should be, and are, available in large chemical corporations. Investors inexperienced in the manufacture of new products should protect themselves by similar action.

The properly equipped chemical engineer, therefore, must have a firm grasp on the economics of the problem and not merely expect that his sphere is limited to materials of construction, design of equipment, and complete knowledge of the unit operations. The ideal process must be a modification that is not only efficient in itself but designed and placed to meet the economic dicta.

Having assumed that all of the above requirements have been determined with the greatest accuracy in the light of the information available, the next step for the chemical engineer is to collect the data necessary to adapt the laboratory process to pilot-plant scale. Most chemical processes present new problems in one or more steps that are not standardized operations. In this case, special equipment must be designed or even invented for the purpose. Other steps of the new process can use available unit-operation equipment. Equipment accessories are available for use without modification. The first instance requiring special design or invention may consume large sums of money and time. The proper selection of available unit-operation equipment often entails considerable experimentation based upon related experience. The choice of accessory equipment is largely a matter of judgment, based upon experience and guaranteed performance by the manufacturer.

Many examples of the transfer of processes from the laboratory to the pilot plant could be given, but without going into detail these may be illustrated by one example.

Maleic acid produced commercially only by the catalytic oxidation of benzol provided a cheap raw material for the production of malic acid. Prior to this synthesis, malic acid was made only in a small way from maple sugar, despite its wide occurrence in many fruits. Its

In developing a chemical process through the laboratory and pilot plant to full-scale operation, many new problems are presented that are not standardized operations. In some cases special equipment must be designed or even invented for the purpose. The proper selection of available unit-operation equipment often entails considerable experimentation based upon related experience. And the choice of accessory equipment is largely a matter of judgment, based upon experience and guaranteed performance by the manufacturer

in the literature, but maleic acid not having been available, there was no commercial process in existence.

In the laboratory, maleic acid could easily be converted to malic acid by heating a water solution thereof in a glass bomb tube under pressure. A byproduct, fumaric acid, was formed, so that the equilibrium had to be determined between the three components, the necessary requirement being that the product must contain only malic and fumaric acids, as maleic acid is about as toxic as oxalic acid and cannot be taken internally by man or animal. The conditions for proper equilibrium were determined in glass bomb tubes. Substitution for tartaric and citric acids in effervescent salts, jellies, and soft drinks required non-toxic properties. Toxicity tests of the malic acid produced from maleic acid had to be checked, as the inactive form of malic acid results from the hydration of maleic acid, whereas that occurring in nature is optically active. Eka salt used by persons who cannot tolerate common table salt is an example of the non-toxicity of the salts of malic acid for such a purpose. The equilibrium between malic acid and fumaric acid required their separation. Fortunately, the latter is quite insoluble and can be filtered from water solutions of the former. Even so, it was necessary to investigate the toxic properties of fumaric acid, because it is present to a small extent in malic acid produced commercially. It was found to be non-toxic.

Considerable quantities of malic acid prepared from maleic acid of known history were needed for making the above tests and for other possible uses. This early necessitated the selection of materials of construction for autoclaves of larger capacity than glass bomb tubes. Maleic acid is corrosive in water solution and at the start, little, if anything, was known concerning metals resistant to it. Enamel-lined autoclaves were found to be unsuitable. Silica and glass thimble inserts in steel autoclaves were tried, but entrainment and foam caused too much corrosion of the steel shells.

Corrosion tests were conducted on various alloys, and aluminum bronze was found to be the most suitable. This alloy, although sufficiently resistant to corrosion to give a long life for the equipment, introduced a new complication. It was slightly attacked by the acid solution, thereby contaminating the malic acid with small quantities of copper, which had to be removed by purification methods to reduce the heavy metal content below that required by law for food ingredients. After this purification the strongly acid solution had to be decolor-

ized by carbons which were free of compounds extractable by the acid. The purified and decolorized solution had then to be evaporated in equipment which would not reintroduce impurities.

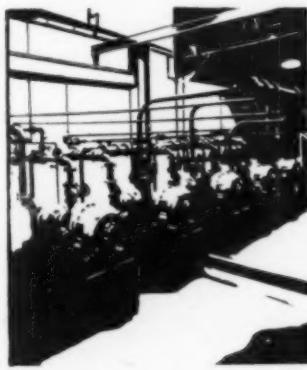
If malic acid solutions are overheated they darken similarly to the caramelization of sugar solutions. This required vacuum evaporation in completely resistant equipment. Concentrated malic acid solutions are thick syrups which solidify to a solid cake upon cooling. This prevented recovery by crystallization and likewise the opportunity for removing small quantities of impurities in the mother liquor. Spray drying likewise retained whatever impurities were present in the solution mixed with the product in powder form, and still worse, the trade, accustomed to buying crystalline or granular tartaric and citric acids, did not want a solid acid in the form of an impalpable powder. The form of the product created sales resistance. All of these difficulties arose in the path of commercial reduction to practice of a process which was simplicity itself in the laboratory. Needless to say, the chemical engineer on a job of this kind has plenty of opportunity to exercise his ingenuity and call upon his experience. This example demonstrates the absolute necessity of orderly and methodical procedure, beginning with the economic situation and following the development through the laboratory and the pilot plant.

The chemical industry, unlike most of the strictly fabricating industries, such as textiles, steel, and cement, produces a greater variety of byproducts. Very often these byproducts weigh between six and ten times as much as the main product. This is especially true in organic synthesis, and profitable production frequently is more dependent upon the yields obtained from the inorganic chemicals used than upon recoveries based upon the organic raw material charged to the process. Byproduct credits are important in lowering costs but confusing in determining them. Occasionally, they even approximate the raw materials used in the process. In general, the organic manu-

tacturer is fortunate when the cost of raw materials is negligible and there is a single finished product to sell. Such an example is seldom encountered. In the case of the malic-acid synthesis described above, the raw materials are maleic acid and water, except for the purifying reagents, which were negligible factors. The products of the synthesis are fumaric acid and malic acid. Several possibilities presented themselves as outlets for fumaric acid; for example, in baking powders, for producing succinic acid, and a large number of well-known esters.

It was found feasible, however, to convert fumaric acid completely into malic acid by repeated return with water to the autoclaves, each time, of course, re-establishing the known equilibrium proportions of malic and fumaric acids. The sole product of the process could, therefore, be malic acid. It seems far better to produce whatever fumaric acid is required direct from maleic acid by a direct process in which fumaric acid is the sole organic product.

Numberless other examples are known to all workers in the industry and can be cited, but it is our experience that the possible combinations of many variables lead to an endless number of process pictures. The underlying principle to guide us commercially is the necessity for economic appreciation of the process and product. This, combined with experience gained in the handling of diverse problems, helps in the solution of any problem, but technical success must make haste slowly through the logical steps of the laboratory and pilot plant before full-scale operations are attempted. Each step in the series continuously presents an opportunity to correct our preliminary cost calculations made solely as an intelligent guess when the process was merely an idea. Should accumulated data show that our original premise was wrong in any way, a halt should be called to consolidate our position. Discretion is the better part of valor and retreat is better than useless loss by continued advance.



SIX REASONS FOR REPLACING EQUIPMENT

◆ OBSOLESCENCE IN MOST PROCESS INDUSTRIES results from a combination of economic and technical considerations. Equipment is rarely replaced because of any physical deterioration such as the actual wearing out of existing apparatus. In the opinion of a well-informed chemical engineer in the petroleum industry, obsolescence is usually due to one of the following causes:

1. Existing equipment, although in good physical condition, may not produce the desired quality of products from the available raw materials. For example, the increasing demand for anti-knock gasoline can be met from certain types of crude oil only by a change in process and equipment.

2. The cost of ground space or other factors in the total operating cost may become excessive with existing

equipment as compared with the possibilities offered by more recent developments.

3. An addition to plant capacity may be necessary, in which case it may be economic to replace some or all of the old equipment with a new installation of larger unit capacity.

4. Often a change in process requiring new equipment may offer flexibility which the older method did not have with the result that the manufacturer may better meet varying market demands for his products.

5. New equipment may offer the possibility of obtaining greater yields of more valuable products. In petroleum refining this would mean a lower percentage of fuel oil and perhaps a higher percentage of premium gasoline.

6. New equipment often permits the conversion of byproducts or waste materials into marketable commodities. Continued production of non-salable byproducts may necessitate more and more provision for storage within the plant or the disposal of the material at an absolute loss. In such cases the investment in new apparatus is sometimes warranted even though the process is not directly profitable as an independent operation.

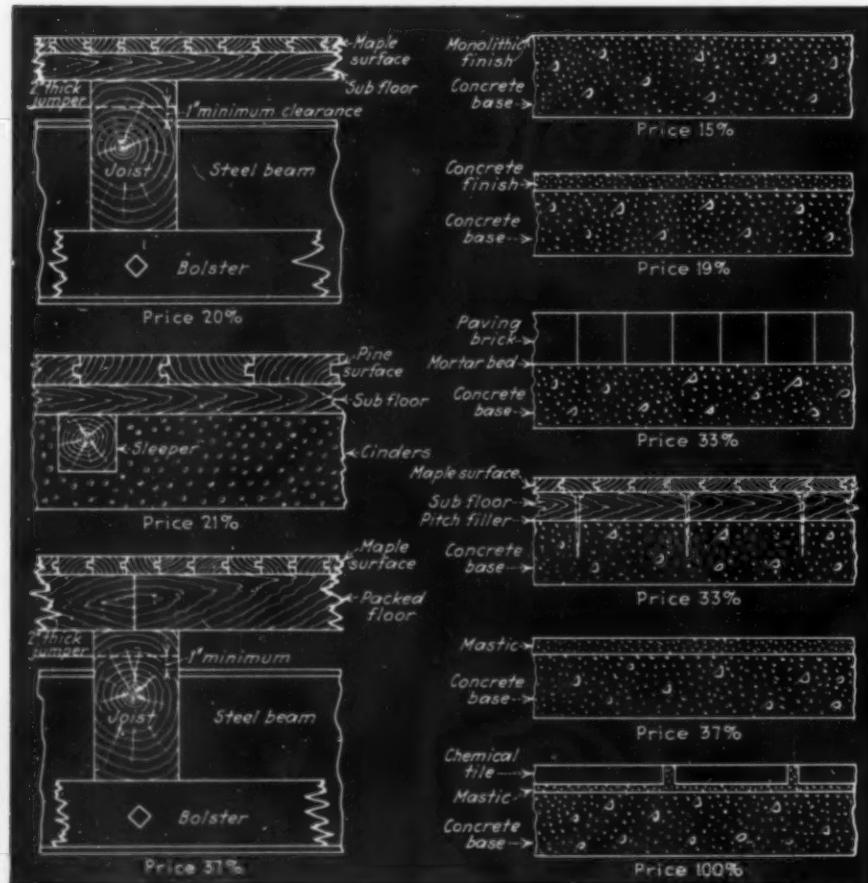
BUILD THE PLANT TO FIT THE PROCESS

By HARRY E. STITT

Chief Engineer, The Austin Company
Cleveland, Ohio

◆ TO THE MAN WHO HAS STUDIED THE economic history of the United States it is apparent that the foundations of most fortunes are laid during business depressions. The present depression is determining which businesses are destined to assume leadership in the next decade. It is through taking advantage of periods of low prices to accomplish the construction of new and efficient plants, the elimination of "white elephants," the rearrangement of equipment, the coordination of production processes, the erection of needed additions, and the improvement of working conditions that the new leaders come to the fore. They strip their decks for action by equipping themselves with plant facilities designed and geared to new conditions.

Approximate Cost of Various Forms of Factory Floor Construction, Expressed in Per Cent of Cost of the Most Expensive Floor Shown, a Chemical Tile Floor Bonded With $\frac{1}{2}$ In. of Mastic to a 4-In. Concrete Sub-Base



Plant of the Hooker Electrochemical Company at Tacoma, Wash.

Industries of the chemical engineering group cover such a wide range that it is almost impossible within the confines of this article to deal in particulars applying to any one field. Broadly speaking, the problem of production can be summed up in one question, "Does your plant fit your process and product?" Many American industries are operating at a loss under efficient management because of costly misfit plants.

Now is the time for management to subject itself to a most searching catechism. "What factors should govern the general location of our plant, and which the specific location? Is our present location suitable and are our present facilities adequate and up-to-the-minute?" These are questions of the sort that must be asked and answered. Some of them may suggest investigations and changes that will reveal the weakness of plants not up to par and pave the way to profits.

Undoubtedly, one of the most important points in efficient factory operation is the question of building design. The process and the materials handled will indicate the general design requirements. Careful attention must be given to the type of floor, structural frame, walls, and roof. There are many cases of misfits in this respect, and only experienced engineers can determine the proper building practices. However, information regarding relative costs of different forms of structure is valuable for preliminary survey purposes and this the three "blueprints" appearing in these pages supply for types of floors, walls, roofs, and roof waterproofing most likely to be used in chemical plants.

Even more important than structural materials in its effect on building efficiency is the question of single-versus multi-story construction. Our

Comparison of Single-Story and Multi-Story Buildings

Based on two buildings each having a total area of 72,000 sq.ft. One building is six stories, 60 ft. wide x 200 ft. long; the other is one story, 150 ft. wide x 480 ft. long.

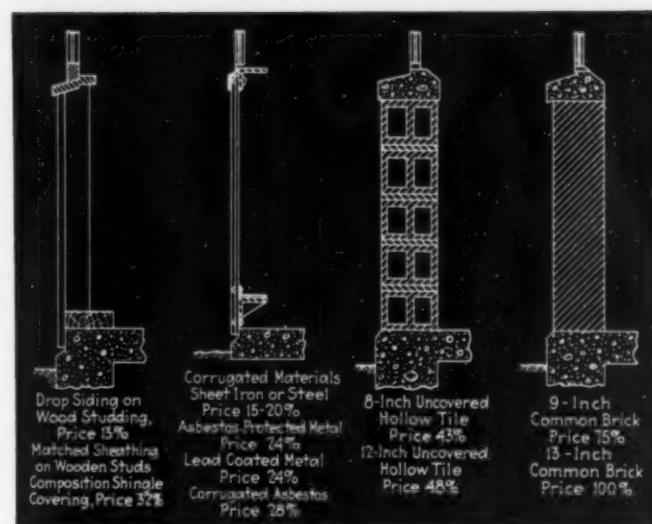
	Multi-Story Square Feet	Single-Story Square Feet
Stairs	2,160	...
Elevators	1,512	...
Approaches	3,600	...
Outside walls	3,120	1,260
Columns	2,976	1,168
Total	13,368	2,428
Total area	72,000	72,000
Area lost	13,368	2,428
Usable area	58,632	69,572
Per cent of usable area	82 per cent	96 per cent
Land required	1/2 acre	2 acres

Comparative Costs

	Multi-story	Single-story
Two stairways	\$10,476	...
Two elevators	20,412	...
Approaches	4,500	...
Outside walls	34,008	\$18,900
Interior columns	5,400	2,208
Exterior columns	5,928	1,620
Total	\$80,724	\$22,728
Floors and roof	50,276	\$131,000
Land (\$6,000 per acre)	3,000	12,000
Grand total*	\$134,000	\$110,000
Price per square foot (including heating, lighting, plumbing and elevators)	\$1.82	\$1.36
Price per usable square foot†	2.24	1.41
Price of land and building per usable square foot	2.29	1.58

*Only when land costs \$22,000 per acre will the grand totals in the two cases be equal.

†If land costs \$34,825 per acre the price per usable square foot will be equal in the two cases.

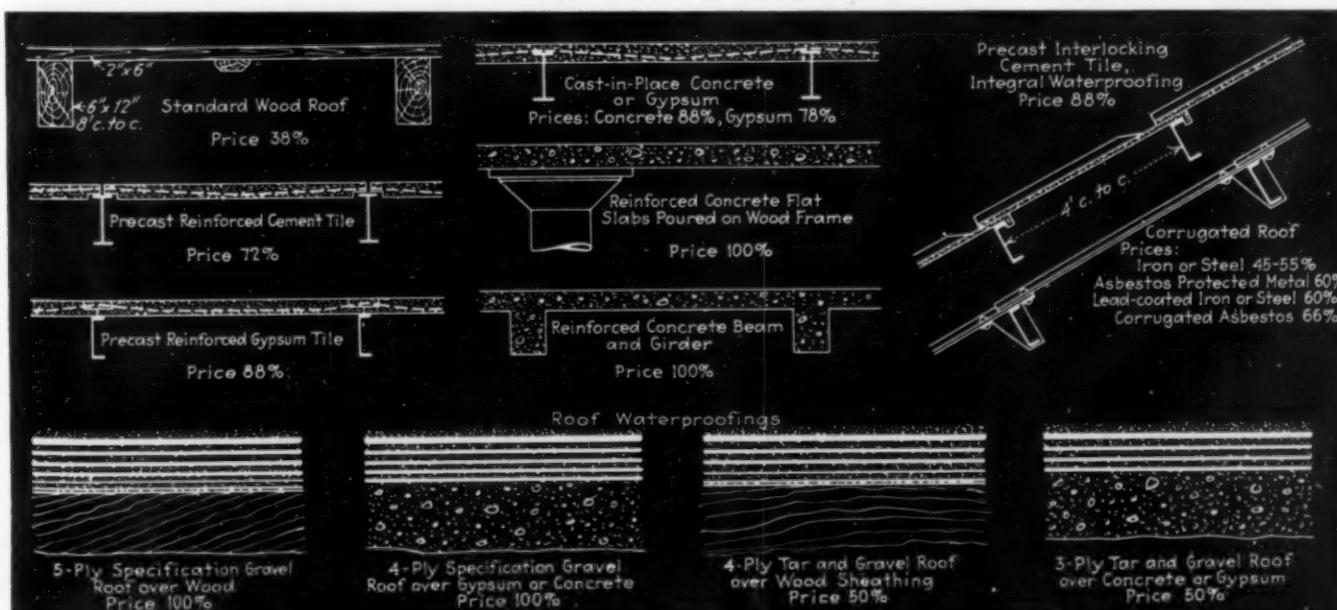


Approximate Cost of Various Forms of Wall Construction Expressed in Per Cent of Cost of Most Expensive Type Shown, a 13-In. Common Brick Wall

Observations have led to two general conclusions: (1) With some few exceptions, the single-story building in industry is less expensive than the multi-story type in original cost, maintenance cost and operating cost. (2) The increasing intensity of industrial competition, making economical and efficient straight-line production virtually a matter of self-preservation for the manufacturer, will result in the further ascendancy of the single-story plant in the great majority of cases.

It is recognized, of course, that conditions in certain of the chemical engineering industries may continue to require the multi-story building. Where gravity flow from point to point in the process is absolutely necessary, use of a single-story building may not be possible, although in many plants equipment can be supported at different levels within a tall single-story building, with

Approximate Cost of Various Forms of Factory Roof Structures and Roof Waterproofings, in Each Case Expressed in Per Cent of Cost of the Most Expensive Type Shown; The Most Expensive Roof Structure Shown Is the Concrete Slab Cast on Wooden Forms (or the Concrete Beam and Girder Type) and the Most Expensive Waterproofing, the 5-Ply Specification Roof



open stairways and working platforms independent of the building walls.

In other cases where plant additions must be made in congested areas, space for single-story construction may not be available except at prohibitive cost. However, for the greater number of instances where conditions demanding the multi-story building are not a factor, it will be shown in what follows that the single-story building offers very attractive advantages.

The general tendency of industry in recent years to move from congested central districts to outlying communities has been attended by a great increase in the number of single-story buildings. The two tendencies have paralleled each other so closely that the erroneous impression sometimes arises that single-story construction is economical and efficient only where land is cheap and taxes low. As a matter of fact, most modern industry is coming to find out that the single-story type is preferable, almost without regard to taxes and land values. Indeed, for many industries, the single-story building is the most efficient and economical, whether the land costs \$5,000 or \$200,000 an acre.

For convenience in comparison, take a building of each type having a total area of 72,000 sq.ft. One building has six stories and is 60 ft. wide and 200 ft. long; the other is a single-story structure, 150 ft. wide and 480 ft. long. Specifications for both buildings include fire-resisting materials which meet the requirements of insurance companies for reasonably low insurance rates. Notwithstanding the fact that multi-story buildings generally are built on more expensive land than single-story buildings, the price of land per acre has been assumed to be the same in each case. A comparison of the two types appears in the table on page 198. It is to be noted that only when land costs are at the very high rate of \$22,000 per acre will the two total land and building costs become equal. Furthermore, the cost of the land has to reach \$34,835 per acre before the price of land and building per square foot of usable area will be equal in the two cases. Even this figure neglects the advantages of the single-story building that are less easily evaluated than first cost: namely, factors such as lower operating expense, better supervision, and increased efficiency of operation.

It is a common impression that multi-story buildings are less expensive per square foot than single-story buildings. There are two main reasons for this belief. First, it is generally observed that the structural floor of a multi-story building serves also as a ceiling for the story directly beneath. In contrast to this, the single-story building naturally must have a floor and roof for every square foot of floor space. A second reason is that almost everyone has the erroneous impression that basements of multi-story buildings cost practically nothing. Thus, since most multi-story buildings have basements, the assumed low cost of the latter seems to help reduce the cost per square foot of the entire multi-story building. Nothing could be farther from the truth.

The first advantage mentioned above for the multi-story building is a real one, as can be observed from the tabulated figures, where the cost of floors and roof is greater for the single-story structure. However, the second is totally false. Practically all basements must be excavated. In addition, basement walls are heavier than other walls in all buildings, and considerable expense for waterproofing of the basement walls and floor is entailed. Even the advantage in expense of floors and roof possessed by the multi-story building disappears in

the face of other conditions. The cost of stairs, elevators, approaches, outside walls, and interior and wall columns bulks so high in the multi-story building, as compared with the similar items in a single-story building, that the advantage is offset several times.

Cost of elevators and their commonly required inclosing walls is a large item and most multi-story buildings of fair size require either two freight elevators and one passenger elevator, or one of each type. Building codes usually call for at least one stairway at each end of a multi-story building, and these must be inclosed in fire walls at added expense of several thousand dollars.



Design of This Multi-Story Building Required Provision for Heavy Floor Loadings; Note Heavy Reinforcements for Upper Floors

The frequent heavy live-load requirements put on multi-story building floors often still further increase the cost of multi-story construction. In the single-story building, the load the floor will carry usually is limited only by the bearing value of the soil on which the floor rests. Most soils have a bearing value of thousands of pounds per square foot.

It will be evident from the tabulation that the price per square foot of gross area in the multi-story type exceeds that of the other type by 46 cents, even before any adjustment is made for lost areas. The superiority of the single-story type, however, is not confined to the sole advantage of lower costs, important though that advantage is. It is the usable floor area, not the gross, which is of vital importance. A building is an investment of capital, and returns on the investment in an industrial building depend on the amount of space which the arrangement makes available for efficient production, as well as the relative cost per square foot.

In the multi-story building, \$24,330 will be invested in non-productive areas, as against \$3,302 in the single-story. If we calculate the cost of both building and land, we find that the single-story building, because of its greater usable floor area, will pay a return on the investment more than 45 per cent higher than the six-story building.

Flexibility is another important advantage of the single-story building. If a manufacturer finds it necessary to effect radical changes in product or method, he may find a multi-story building unsuited to the new production scheme, whereas a single-story building lends itself to almost any kind of arrangement, because of the absence of many columns and the uniformly high floor-loading capacity.

In the single-story building, materials can be delivered directly to or shipped directly from many departments,

avoiding clogging of the elevators. Transportation both by truck and rail is less difficult, because there is less congestion in the outlying districts, where single-story buildings are so generally built. It is estimated that the single-story building saves about 20 per cent of the productive time of both employees and management. Supervision is easier, because an unobstructed view is obtained. Likewise, a single-story building lends itself more readily to ventilation and lighting, because both side walls and monitors are available for these purposes.

The superior adaptability of the single-story building to the installation of labor-saving machinery also has a bearing on labor relations. Fatigue is the great enemy of industrial efficiency. Whereas labor-saving machinery formerly was used solely to increase production, it is now being employed to reduce the effort of the worker.

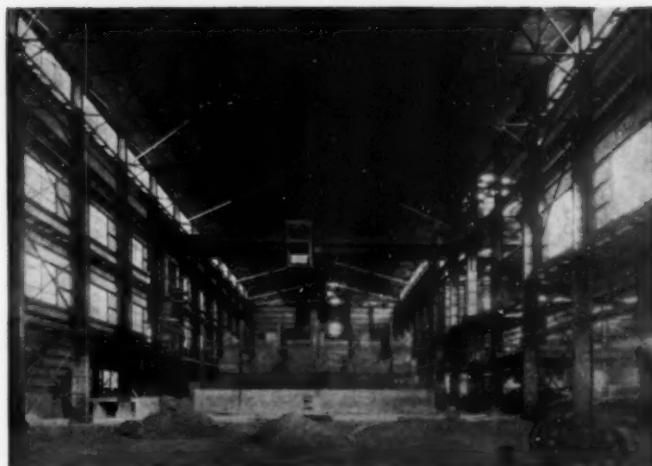
One owner of a large business recently moved his main center of operations from a multi-story into a single-story plant. In order to use the old building, he located an associated line of business in it. Thus he had an advantageous opportunity to compare the operations in the two types of plants. His conclusions were that the incidental benefits he received due to reduction in accidents alone in the single-story building justified all his trouble in erecting and moving into the new plant. This accident decrease arose from the absence of stairs and elevators. It took no account of the dollars and cents benefits he enjoyed from lessened production cost, better supervision, and more efficient operation.

These statements do not mean necessarily that the multi-story building will be entirely supplanted, for, as was noted in introducing the subject, there are some purposes which the multi-story structure alone can serve best. We hold no brief for either, exclusively, for we design and build both types as the requirements may indicate. But the facts do show that in a great majority of cases the progressive manufacturer is disposing of multi-story plants in favor of the single-story type.



This Multi-Story Building of Reinforced Concrete Provides Good Natural Lighting and Ventilation

Questions of whether the building design should call for a single story or more are vitally important, but they are not the only considerations. For instance, there are some chemical plants that can operate to the highest degree of efficiency in standard type buildings. Such plants are indeed fortunate, for their building costs are substantially reduced. Other plants require highly specialized construction to meet particular production methods. There is a marked tendency among newer chemical plants to use windows or skylights more particularly for ventilating purposes than for lighting, and this leads



Good Natural Lighting and Ventilation Are Apparent in This Single-Story Construction Applied to a Fertilizer Plant; Note Crane Facilities

to one of the most important subjects in industry today, and that is the matter of "controlled conditions."

Our company is now designing and building industry's first windowless factory, a "controlled-conditions" plant for the Simonds Steel Industries at Fitchburg, Mass. This one-story building, 360 ft. wide and 560 ft. long, contains more than 200,000 sq.ft. of floor space, and yet there is neither a window nor a skylight in the entire plant. In fact, the project now is completely walled in, the roof is on, and the interior is being finished. In a short time the permanent lighting and heating systems will replace temporary ones now in use.

Every step in the design of this revolutionary plant has been developed by scientific research. Adequate artificial light and ventilation will be provided. After exhaustive experiment and study, the systems selected have been found to create working conditions far more satisfactory than obtains in the ordinary plant. The plant will be illuminated with a lighting intensity of 26 foot-candles on the working plane; the air will be changed completely every few minutes; noise will be muffled; everything to eliminate fatigue of workers and increase efficiency will be provided.

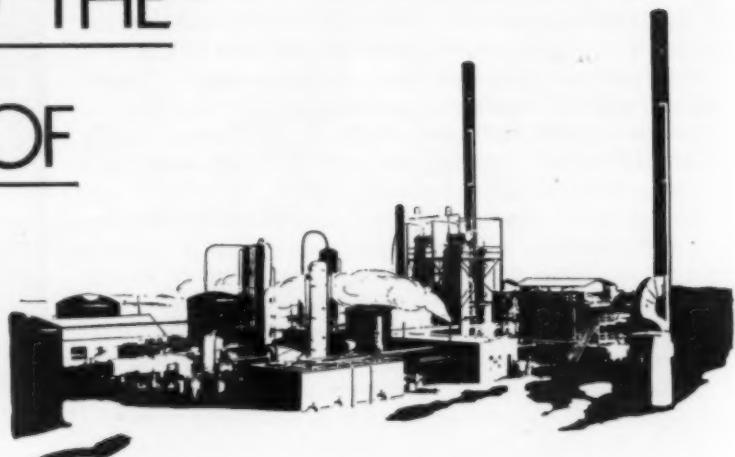
Many chemical plants are operating today under semi-controlled conditions. They depend largely on artificial light, but when this is combined with daylight, the resultant illumination usually casts shadows. Certain plants, such as dye or pickling houses, having baths which give off volumes of steam and fumes, depend on air conditioning to control humidity. Others could vastly improve working conditions and increase efficiency if they were to do likewise. It is evident, therefore, that chemical engineering industries have gone part of the way in controlling conditions. The question naturally arises as to the advantages of going all the way, thus placing plants years ahead of competition. It is our belief that certain types of chemical plant could profitably adopt the windowless factory plan.

Even more firmly we believe that the period is at hand when industry must make up its mind, either to sink or to swim. Competition has stiffened in a period of falling prices. Never have operating economies and profits at fractional capacity been more desired than they are today. New and better products and lower manufacturing costs are being sought on every hand. Research laboratories are playing a vital part in this new economic era, but their efforts can be of little practical value if efficient and adequate plant facilities are not available.

SUIT DESIGN TO THE REQUIREMENTS OF FABRICATION

By O. S. SLEEPER

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◆ EQUIPMENT MANUFACTURERS SERVING the chemical engineering industries have kept pace with general progress in the development and application of advanced methods of design and fabrication. This progress has resulted principally from the introduction of new materials, improved fabricating machinery, and the growth of welding technique to a highly satisfactory state of dependability. The last decade has witnessed changes in equipment design and fabrication methods that are producing for the chemical engineer more suitable and more efficient units than ever before. It is the purpose of this brief survey to cover only the guiding principles now in use in this field.

The production of a unit—be it evaporator, still, dryer, or any of the more or less standardized pieces of equipment—involves first and foremost intelligent design. Any unit should be regarded as a device for applying on a large scale, as perfectly as possible, the fundamental chemical or physical principles involved. This viewpoint necessitates first an analysis of the operation to lay bare what principles are involved, and then usually a com-

promise, because of the limitations set by cost and other practical reasons. The aim of design should be maximum "financial" efficiency, even though in most cases this results in a sacrifice of thermal or productive efficiency. Intelligent design considers equipment life, maintenance, obsolescence, safety, and a multitude of other factors just as carefully as it strives for B.t.u. efficiency, since these in all cases are significant and frequently dominating. A proper evaluation of many of the items comes only through blending experience with fundamental science. Such a compromise constitutes good design. Hard-and-fast rules cannot be laid down to cover the design of the manifold types of equipment required in modern chemical industry. It is important to note that this compromise is gradually shifting, so that fewer concessions to physical limitations of fabrication are necessary. We are obtaining a more perfect realization of theory in practice.

Chemical equipment manufacturers face a condition hardly found in any other industry. Practically every unit installed is specially designed and constructed to

conform to the particular operating conditions and requirements of the process in which it is used. Even plants producing the same finished product differ greatly in operating detail and in the specifications of equipment used. Lack of standardization is perhaps more marked in this industry than in any other. Without arguing the necessity or desirability of this condition, it is sufficient to state that it gives rise continually to many problems which the equipment fabricator must solve. Mass production benefits cannot be obtained and unit costs are necessarily high. It is generally felt that improvement in this condition is in standardization can be made.

Selection of materials of construction is the initial step in the successful building of equipment. Here the

Electric-Arc Welders Working on Special Equipment

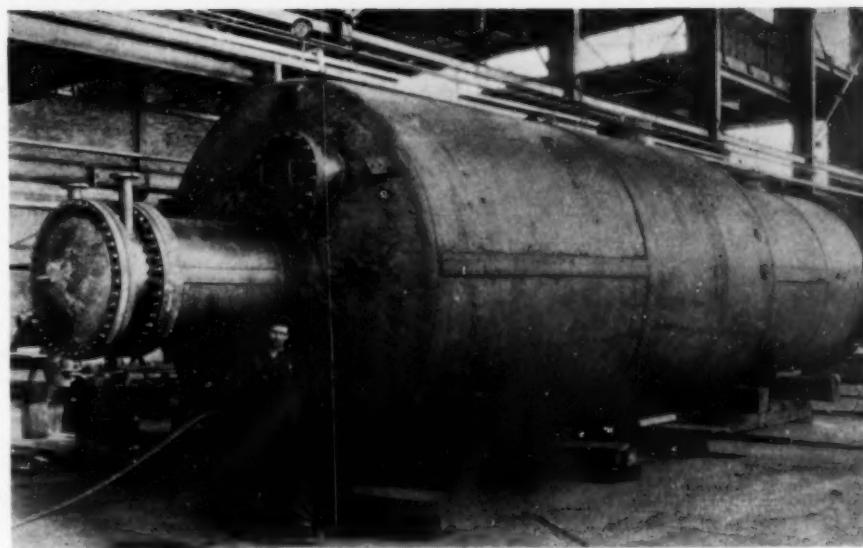
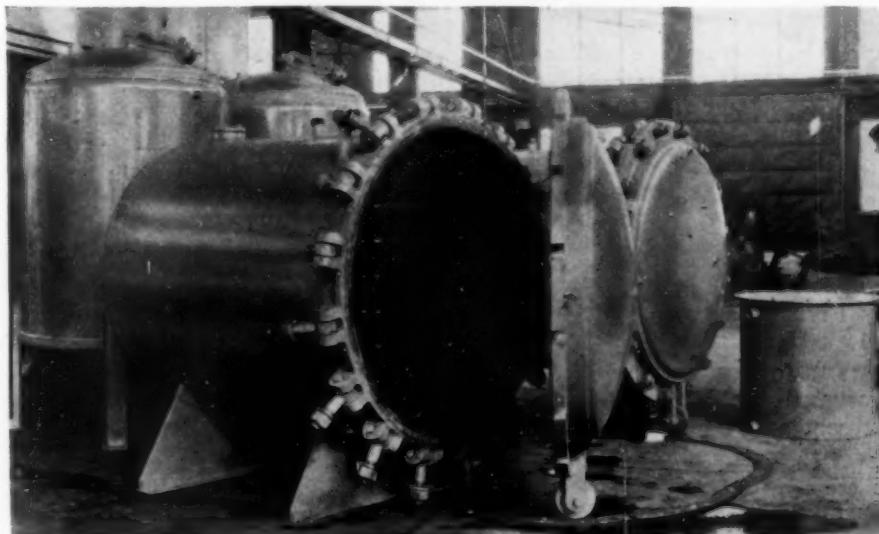


introduction of new alloys and improved casting and forging methods has greatly widened range of choice. Frequently, the corrosion-resistant properties of metals are determining considerations. There are available today special metals particularly resistant to the action of the hundreds of solids, liquids, and gases handled in industry. Many of these, however, while satisfying the chemical specifications, do not measure up to the requirements in such matters as tensile strength, ductility, machinability, and cost. In some instances, as, for example, equipment for the food industries, corrosion properties may assume predominating importance. Sometimes conditions to be met permit a choice between cast and either riveted- or welded-plate construction. While each method will continue to have its field, the trend is definitely toward the latter.

The manufacture of castings involves pattern work, coring, molding, casting, and then pattern storage, each with its overhead, breakage and time consumption. Fabrication from plates is more direct and necessitates fewer operations and smaller overhead. The finished products also differ in important particulars. In general the cast unit is heavier and more easily damaged by shock. The thicker walls of castings reduce the rate of heat transfer and consequently increase the area of heating surface required.

An example of what can be done by taking advantage of the possibilities of welding is furnished by an operation now under consideration by this company. For some years we have used casting methods in making an inside-machined, steam-jacketed pan, provided with agitators and having a center hub, outlet door, supports, and driving mechanism for the agitator. While entirely satisfactory, this job presents unusual difficulties and large foundry losses occur. Careful consideration has resulted in the development of an all-steel welded construction superior in many respects to the former machine.

Welded Combination Pressure and Vacuum Tank With Cast Steel Ring and Flange



All-Welded Vacuum Bubble Tower, Size, 10 Ft. 6 In. x 33 Ft.

Within the field of casting there is still considerable latitude as regards choice of metal and production methods. The actual composition, melting and casting procedure, coring methods, and so on, determine the quality and life of cast equipment. Fabrication from steel sheets or plates by rolling, bending, and then riveting or welding allows even greater latitude than in casting, because of the availability of new alloys in a variety of sizes and shapes.

We hold no brief for either riveting or welding methods, nor for gas as distinguished from electric-arc welding. The many factors that enter in a discussion of the merits of these methods have been frequently reviewed. The wide-awake equipment manufacturer employs all of them without prejudice. In many instances both riveting and welding are combined for better results in the same unit. With the exception of the A.S.M.E. Boiler Code Committee, which has not yet approved welding for fired pressure vessels, welding has been generally accepted and adopted and is finding increasing application. For pressure-vessel construction, welding permits the testing of the completed unit at considerably higher pressures than are permissible with riveted construction. Costs in general are lower with welded construction. This results from the elimination of pattern and foundry work and the allowable reduction in weight of metal, as well as from the speeding up of production rates. Even in comparison with riveting, welding reduces production costs.

It is difficult to generalize as to welding speeds, since these vary enormously with the complexity of design, thickness and kind of metal. Electric-arc welding on the average is about 20 per cent faster than gas welding. Considering a $\frac{3}{8}$ -in. plate, arc welding speeds are between 3 and 4 ft. per hour, while gas welding may vary between $1\frac{1}{2}$ and 4 ft. per hour. An important difference is found in the desirability of heat-treatment after welding. Gas

welding, especially for thick plates, involves the deposition of more metal and the fusion and heating of a larger area of plate than does arc welding. Heat treatment, therefore, is more common with gas welding than with electric welding. A saving in weight of welding rod with the arc method sometimes is possible by double welding from both sides, using a double V rather than working only from one side in a larger single V.

Welding enters into design considerations in another important particular. Lugs, supports, stiffening members, nozzles, reinforcements, and all manner of connections may be placed exactly where desired. With riveted construction it is necessary to select the location of such pieces with due regard to drilling and riveting requirements. It is entirely possible to use steel castings or forgings for accessory parts and weld them directly into the steel body.

Oxyacetylene welding has furnished the fabricator with a rapid and inexpensive tool for a variety of purposes. By the use of special equipment, it is possible to burn openings or holes in steel with remarkable accuracy. In many cases no further machine work is required and nozzles and other connections may be inserted and welded into place directly.

In the field of chemical equipment manufacture are many concerns specializing in the production of standard parts and shapes. It is good engineering as well as economy to purchase such items for incorporation into the finished unit rather than to attempt the fabrication of them when and as needed. The policy of 100-per cent manufacture inevitably leads an equipment fabricator into costly development work and avoidable expense. Good design contemplates the utilization of such highly

developed engineering skill and experience as may be found in companies specializing in the manufacture of special shapes and accessories.

Size of units is another design question that must be given attention. As in other fields, the trend is toward units of increasing capacity. The equipment manufacturer usually can devise fabrication methods for any required dimensions. The immediate limitation on size, therefore, is set by transportation facilities. Many units must be so designed that shipment may be made in sections to be assembled at their destination.

A new development in design that is rapidly finding favor in equipment intended for severe service conditions is the use of corrosion-resistant liners inside of shells of less resistant metal. Light-weight alloy-steel sheets may be formed and fitted inside of ordinary steel or cast-iron bodies to provide replaceable surfaces of long life and excellent resistance to chemical attack. In some cases, it is feasible to cast high-silicon iron inside a steel shell to obtain the desired results. Not only has this method accomplished considerable increase in equipment life but it has also resulted in appreciable reductions in cost.

It is, of course, impossible to cover adequately the field of design for proper fabrication in this brief space. We shall be content with pointing out that the chemical engineer concerned with equipment design problems has many varied and powerful tools at his disposal and that most of his ideas and requirements can be effectively served by equipment fabricators with modern equipment. The chemical engineer can, however, without sacrificing any efficiency keep in view some of the problems of fabrication and assist in progress toward reasonable standardization of units.



WHAT IS THE BASIS FOR RETIRING EQUIPMENT?

By R. L. COPSON

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◆ CONTINUAL IMPROVEMENT IN THE design of process equipment is characteristic of chemical industry. This improvement particularly has for its object the reduction of operating costs. Management is thus frequently confronted with the question of whether to retire present equipment which is not yet worn out in favor of a new and improved model. This problem has recently been discussed with references to the mining industry by Bucky in *Mining and Metallurgy* for February, 1930 (page 99), and by Fernald in the same journal for May, 1930 (page 267).

In considering the economics of the retirement of chemical plant equipment, let us first discuss the criteria that may be used for comparing the present equipment with the proposed new model.

1. The annual costs of operating each piece of equipment may first be compared. The fact that the new model will operate at a lower cost is not sufficient to justify its pur-

chase, since the capital cost of making the change must be taken into account.

2. The statement is frequently heard that some new piece of equipment will pay for itself out of increased earnings in a certain number of years. This basis of comparison may be made quantitative by calculating the capitalized value of the annual savings in operation during the life of the present machine, and comparing this with the total cost of scrapping the present equipment and purchasing the new. However, although the new machine may actually pay for itself in a very few years, it does not necessarily follow that its purchase is advisable.

3. The purchase of the new equipment may be considered on the basis of its earning power as an investment. In the ultimate analysis, the purchase of any production machine must depend upon the percentage profits realizable by its operation. The new equipment is an investment, and this is the only rational point of view to take in solving the problem of retirement.

Professor Bucky, in his paper, has used the percentage return on the investment as a means of comparing the present equipment with the proposed new model, and has illustrated how the calculations for using this method may be made. His treatment is summed up in the following quotation: "It is desirable to replace equipment when the percentage return on the investment in equipment with the new machine is equal to or greater than the percentage return on the investment in present equipment." In other words, if by purchase of the new machine the percentage return on the total money invested in this type of equipment were increased, then the purchase would be advisable; if, on the other hand, the percentage return were decreased, then it would be better to retain the present equipment.

This line of reasoning is not correct in the view of the present writer; it appears rather that the purchase of new equipment should be regarded solely on its own merit as an investment, without comparison with the rate of return realized on the present equipment. If one owns a \$1,000 bond yielding 6 per cent, one will not necessarily refuse to purchase a second bond of the same amount which yields only 4 per cent, merely because the return on the total investment will thereby be decreased to 5 per cent. One will rather consider the purchase of the new bond on its own merits and as compared with other investment opportunities existing at that time. The same considerations apply when it is proposed to make an investment in new machinery for the purpose of retiring the present equipment.

Professor Bucky's treatment is founded upon the fundamental principle that "the success of a business is measured by the percentage ratio of the net profits to the capital invested." Sometimes, however, it is necessary to make a distinction between the total capital invested in equipment and the owned capital of the company, since the two may be greatly different. Therefore, it may be stated more correctly that the success of a business is measured by the percentage ratio of the net profits to the capital put up by the owners of the business. It is always profitable to borrow money at 6 per cent if it can be made to earn 20 per cent, even though the percentage return on the total investment in equipment may thereby be lowered.

In determining the advisability of retiring present equipment and purchasing new, it is necessary to know, first, the total capital cost of making the change, and, second, the increase in profits resulting therefrom. The total cost of making the change includes not only the cost (C) of the new equipment installed, but also the loss (L) due to scrapping the present machine. The latter is the difference between the book value of the present equipment as an operating asset and its scrap or resale value. This difference must be written off the books at the time of making the change, and is therefore a capital charge. Any other expenses involved in making the change, such as production losses during installation, should also be included. Let these miscellaneous expenses be represented by (M).

The increase in profits resulting from the retirement of the present equipment may be calculated from the savings in costs of operation and from any change in the selling price of the product or the cost of raw materials. It is not necessary to discuss here the methods of calculating operating costs, but it is essential that the cost data be complete and accurate if the conclusions based thereon are to be of value. To solve the problem of retirement, it is necessary to know only the increase in profits that will result. If the selling price of the product and the raw material cost are not changed by the replacement, then the annual saving in operating costs is the increase in profits (ΔP). In this case it is necessary to know only those items of cost that will be changed by making the replacement.

Using the symbols indicated in the foregoing, the percentage return (R) on the investment realized by retiring the present equipment and installing the new is:

$$R = 100 \frac{\Delta P}{C + L + M}$$

It is to be noted that the older the present equipment, the smaller is the term (L), and hence the greater is the rate of return realized.

As has been shown, the advisability of making the replacement is determined solely by the rate of return, calculated as above, and as compared with the rate that would be earned by investing the same sum of money in some other way. As in all other kinds of investment, the element of risk enters here. Since the risks in chemical manufacturing are high, the rate of return on an investment in chemical equipment must be high to make it attractive as compared with other investments which may yield lower rates of return but which are safer as to principal. On the other hand, if a number of opportunities for investment exist in a given plant, then those that promise the higher rates of return should obviously be made first.

The following example will illustrate the application of these principles to a particular case:

A certain piece of equipment cost \$25,000 when new. It has been in operation four years, and it is estimated that it will last six years more. Its value as scrap is \$2,000. Operating costs, including steam, power, attendance, depreciation, maintenance, taxes, and insurance, are \$31,200 per year. Depreciation is figured according to the straight-line method. A more recent model of the same type of equipment is offered at \$29,000, and a careful estimate indicates that it can be operated, doing exactly the same job as the present machine, for \$20,500 per year. It is desired to determine whether or not it will be advisable to retire the present machine and to install the new one.

In this case the annual saving in operating costs would be \$31,200 less \$20,500, or \$10,700, and this is equal to the increase in profits. The unamortized value of the present equipment, using straight-line depreciation, is \$15,800. Therefore,

$$L = \$15,800 - \$2,000 = \$13,800.$$

No charge is necessary for production losses during installation. Therefore, the total cost of making the replacement is:

$$C + L = \$29,000 + \$13,800 = \$42,800.$$

The rate of return on the investment is then:

$$R = 100 \frac{\Delta P}{C + L + M} \\ = 100 \frac{10,700}{42,800} = 25 \text{ per cent.}$$

This rate of return is such that the replacement of the present equipment would appear to be advisable, provided that the necessary capital is available or can be borrowed. If the operating costs of the new machine had been \$25,500 per year, then the annual savings would be \$5,700, and the rate of return on the investment only 13.3 per cent. In this case retirement of the present equipment probably would not be advisable, since an investment in chemical plant equipment should ordinarily earn at least 20 to 25 per cent.

It is not always possible to evaluate quantitatively all of the advantages that would result from the retirement of a given piece of equipment. Thus, a new type of evaporator may make it practicable to evaporate to a greater concentration, or it may overcome difficulties due to foaming or entrainment. New improvements in a dryer may reduce the time required for processing. In cases such as these, it may not always be possible to predetermine accurately just how great would be the savings resulting from retirement of the present equipment and purchase of the new.

Making due allowance for all of the above factors, however, it should ordinarily be possible to analyze a particular situation according to a procedure such as that outlined here. Many companies fail to recognize the opportunities for investment which exist in their own properties. It is probably true that in most chemical plants equipment is now in use which could be retired in favor of new machines, to such advantage that a high rate of return would be earned on the investment.

EQUIPMENT ECONOMICS, A ROAD

TOWARD COST REDUCTION

By LYLE STOCKTON ABBOTT

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◆ THOSE WHO HAVE HAD OCCASION TO analyze the various items of cost in the manufacture of chemicals and chemical products are often astounded by four items: First, lost production through enforced shutdowns due to equipment failure; second, labor items for repairs; third, cost of replacement parts; fourth, loss through contaminated products. They would be still more astounded if these items were analyzed from an economic standpoint and an appreciation was gained of how these losses can be reduced through adequate design and the proper and careful selection of materials of construction.

It is a regrettable fact that most purchasers of chemical equipment are concerned primarily with the purchase price and are prone to minimize consideration of the maintenance and the operating losses resulting from the failure of apparatus when in service. Any piece of apparatus is economical or expensive only in proportion to its effect on the total cost of the product being manufactured. Notwithstanding the marked advances made in recent years in materials of construction it must be admitted that most materials are only acid-resisting and not acid-proof. It naturally follows that they have a limited life. Through corrosion or abrasion, and sometimes both of these factors combined, very frequently the shape and size of various parts are seriously altered. This cannot be ignored in the design of chemical equipment and the equipment must be designed either to compensate for these losses or for the ready removal and replacement of those parts most affected. In the vast majority of cases, the difference in cost between the highest priced and the lowest priced piece of apparatus is considerably less than the cost of loss in production occasioned by a breakdown of the equipment when it is in operation.

This is the chief reason for the tendency in the United States toward designing apparatus for a specific purpose, rather than following the European practice of adapting so-called standard equipment. A pump, for example, designed for water service, and perfectly satisfactory for such service, is seldom adequate for chemical handling, even though made of materials resistant to the chemicals handled. Water pumps can be made with close clearances, with inclosed impellers of intricate design, carefully proportioned volutes, and seal rings. Chemical pumps operate under conditions where close clearances cannot be maintained; inclosed propellers foul and unbalance; gases evolved or carried by the liquor

compel modification of the casing; and seal rings cannot be used at all. Continuity and uniformity of performance are of the highest importance, and the whole apparatus must be so designed that when repairs or replacements are required, they can be made with the smallest possible loss of time and with a minimum of expense. Power efficiency can often be sacrificed, and the use of high-priced alloys frequently justified, in order to produce continuity of operation, keeping in mind the ultimate goal, which is the minimum cost of producing a product.

Since the measure of cost of any piece of equipment is not its purchase price but the cost of its operation per unit of production, then the cost of repair parts must also be taken into consideration. Considerable economies can be effected by chemical manufacturers if, when requesting quotations on equipment, they obtain the cost of those parts which must be repaired or replaced from time to time and if they also inquire fully into what provisions have been made by the maker to limit outage in operation.

Purchasers of equipment should receive positive assurance from the manufacturer that all working parts will be made to gage, so that repairs and replacements can be carried out with the least delay. Full advantage should be taken of the facilities offered by properly designed equipment, and such apparatus kept at maximum capacity by maintaining an adequate supply of replacement parts on hand.

When pieces of equipment of short life are used in conjunction with those of relatively long life, duplicates of the short-lived equipment should be provided, preferably cross-connected for immediate use; or in cases where this is not feasible, complete units ready for service should be kept in stock and provision made for quick substitution.

In recent years there has been a constantly increasing number of alloys offered to the chemical industry for the specific purpose of combating corrosion. With their introduction, claims usually are made as to their advantages, most of which are clothed in general terms indicating a wide range of usefulness. As time goes on, manufacturers frequently put forth additional forms of these alloys, drawing in the field of application and recognizing certain limitations, the more progressive publishing specific data as to corrosion loss and adaptability to specific purposes. This is a natural course of events, and those who have followed the development of alloys of high corrosion resistance have come to the conclusion that, while there is no single metal or alloy which has a wide range of economic usefulness, all of these various materials have a field of application when properly selected and applied.

Alloy manufacturers do not publish information which

will enable the prospective purchaser readily to determine what material is most economical for his purpose. Not all manufacturers give data as to specific losses for various chemicals, but rather the bare statement that the alloy is suitable or can be used for certain purposes. Even in those cases where data as to comparative corrosion loss can be obtained or determined, this single set of factors is not sufficient to determine what material can be used for the greatest ultimate economy. There must also be considered such factors as those outlined in the following paragraphs.

Mechanical properties are of great importance because they determine to some extent and perhaps limit the design, and in many cases fix the ultimate weight of the equipment. For example, if all other factors were equal and the choice lay between one of the stainless alloy steels and antimonial lead, the steel would have the advantage, due to the fact that all parts could be made of smaller cross-section, on account of the fact that the steel is superior both in mechanical strength and in stiffness.

Cost of fabrication will vary markedly with different corrosion-resisting alloys. For example, lead and aluminum alloys are easily machined and readily welded, whereas chrome-nickel and silicon-molybdenum steels are frequently very difficult and expensive to machine. High-silicon irons cannot be machined at all but must be cast and ground to size. Nor can they be welded on a commercial basis. The same is true to a greater or lesser extent of many other corrosion-resisting alloys now on the market.

One item often neglected, or at least not given its full value, is specific gravity. Frequently where all other factors balance each other, due consideration of this item will dictate a choice. A light material, although high in price per pound, may actually prove cheaper, volume for volume, than a considerably less expensive metal or alloy. Hence, in considering cost, the purchaser is not concerned so much with the cost per pound of material as he is with the cost per pound or per piece of the finished equipment. And this, of course, will be influenced considerably by the specific gravity of the material chosen.

Corrosion rate often is a weighty factor, but it is not necessarily of primary concern, because its importance varies with the use to which the material is put. For example, if an additional thickness of a cheaper material can be provided at low cost to compensate for loss in a tank lining, a more resistant, higher-priced alloy can hardly be justified, provided that the product will not suffer from the resultant contamination. On the other hand, where the added thickness cannot be used and a comparable loss would occasion a shutdown for replacement, a much higher-priced material may be in order.

Frequently lower priced materials can be used with just as great economy as those enjoying a temporary vogue and extensive selling campaigns. For example, current advertising literature claims that for cold 50-per cent acetic acid such materials as 18-8 chrome-nickel steel, aluminum bronze, and Everdur are suitable. It is true that they are suitable, but aluminum No. 43 alloy is far more economical. Likewise, for cold 66-deg. Bé. sulphuric-acid

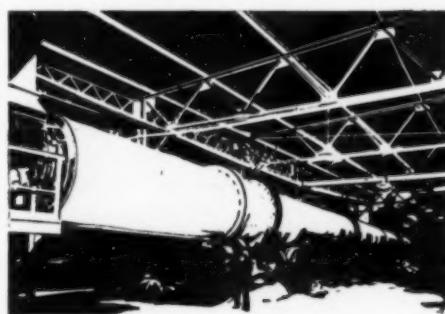
antimonial lead, aluminum bronze, and a host of modified steels are claimed as suitable; but low-silicon cast iron for pumps, valves, and other cast parts is far more economical; and merchant steel plate is a more economical material for tanks and pipe lines. The corrosion loss of 18-8 chrome-nickel steel when handling nitric acid is practically negligible, but the same is true of a 20 to 25 chrome iron. This latter material has the further merit of being much cheaper in cost and far easier to machine. As another example, it is said that for 3-per cent sulphuric acid we should use antimonial lead, aluminum bronze, or Monel metal. While it is true that these materials will be satisfactory in service, it is also true that Nimol, a nickel-copper-chromium cast iron, is a much cheaper and equally satisfactory material. Such examples could be multiplied at great length.

Closer co-operation between chemical manufacturers, alloy producers, and equipment manufacturers will be productive of mutual benefits. It will not only decrease the cost of equipment to the chemical manufacturer but give a more rapid allocation of the many materials of construction to their proper competitive positions, which is an obvious advantage to both alloy and equipment manufacturers in increasing the rapidity of return on their research and development.

In the selection of equipment a factor often overlooked is size. Many pieces of equipment are needlessly bulky and occasion undue overhead charges due to excess plant space occupied. A case in point came up several years ago when, on account of an increased production schedule, a soap manufacturer found it necessary to build an entirely new plant for the evaporation of soap lyes. Proposals for evaporators were called for and those received differed only slightly in price. But, because of improved design, one type of evaporator occupied only slightly more than half the floor space of the other types. The resulting saving in building cost alone amounted to more than a third of the cost of the evaporating equipment. To this saving should be added the difference in costs of operation, such as decreased capital charge on plant, insurance, cost of heating and lighting, and building depreciation. Although this factor is not so important where apparatus is to be added to an existing plant, it may be of considerable moment when new buildings or alterations to old buildings are necessitated and any piece of equipment is being evaluated. In such cases this factor of size and its influence on building cost must be taken into consideration.

Manufacturers often are confronted with the problem of an existing plant or piece of apparatus which is so old or of such an obsolete type that they believe it should be redesigned or entirely abandoned. In such cases a direct comparison between the cost of production of the

new and old is not sufficient. An increase in investment is justified only when the new will pay a reasonable return on its own cost plus an amount equal to the revenue obtained from the old. This proposition is not peculiar to the chemical industry and has had considerable attention. A complete mathematical exposition of its treatment was given in an article by Halbert P. Gillett in *Engineering & Contracting*, July 14, 1915.



EVOLUTION OF A NEW

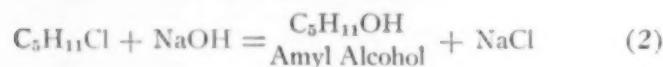
CHEMICAL INDUSTRY

Design problems met in the building of a new industry, the synthesis of amyl compounds from the pentanes, through the numerous steps in laboratory, process and plant development

By LEE H. CLARK

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◆ THE OPERATION OF A PLANT FOR THE synthesis of amyl chlorides, amyl alcohols, and the corresponding acetates was begun at Belle, W. Va., in the fall of 1926, by the Sharples Solvents Corporation. Chemical reactions involved in the production of these primary products may be represented quite simply:



Inasmuch as the pentane used in the process is composed of two of the possible three isomers and the products obtained include six out of a possible seven isomeric chlorides, six alcohols corresponding to these chlorides and five acetates, these simplified equations do not give a complete picture of the chemistry involved. However, they do represent the primary process steps with sufficient clearness to follow the evolution of those steps from the beginning of research work to their present operating status.

The occurrence of side reactions leading to the formation of other byproducts, those chemical interlopers which rob at the expense of yields of primary products, has been discussed previously by Ayres (*Ind. Eng. Chem.*, Vol. 21, p. 899, 1929), together with more detailed descriptions of the fundamental reactions. Only so far as these byproducts affect engineering design will they be mentioned later.

There are available several descriptions (S. D. Kirkpatrick, *Chem. & Met.*, Vol. 34, p. 276, 1927, and Clark, *Ind. Eng. Chem.*, Vol. 22, p. 439, 1930) of the process steps as at present practiced.

When operations were begun the plant was, and still is, the only one of its kind in the world. There was

but meager chemical or engineering precedent to assist in its original design. In spite of several years of preparation carried on in both laboratory and pilot plant, wholesale changes have occurred in engineering details. From an engineering viewpoint perhaps the most significant feature of its evolution has been the change from predominantly batch operation to substantially continuous processing of materials.

Two batch processes survive, involving only the final distillations of alcohols and acetates to produce the marketable products. These operations lend themselves readily to this procedure.

A similar change has occurred in the production of pentane from natural-gas gasoline. Originally, gasoline was purchased at the plant and the pentane fractionated from it in batch operation. No supplier of special fractions of gasoline could be found when operations started. Within the last few years many of the oil companies have equipped themselves to produce pentane and other special fractions of their products on large-scale continuous distillation equipment. Pentane is now purchased from outside sources.

It is almost axiomatic that substantial operating economies have been possible on the processes altered to continuous operation. Operating labor has been reduced and output has increased without corresponding increases in equipment.

At a time when many other investigators were turning their attention to utilization of the tremendous production of natural gas in excess of that required by the carbon-black industry and for fuel in restricted terri-

Table I—Changes Made in Processing

Product	Operation	Mode of Operation
	Original	Present
Amyl chloride	Chlorination of pentane	Continuous Continuous
Amyl chloride	Distillation	Batch Continuous
Hydrochloric acid	Absorption	Continuous Continuous
Amyl alcohol	Hydrolysis of chloride	Batch Continuous
Amyl alcohol	Purification by water-washing	Continuous (Abandoned)
Amyl alcohol	Purification by distillation Continuous
Amyl alcohol	Fractional distillation	Batch Batch
Amyl acetate	Esterification of alcohol	Batch Continuous
Amyl acetate	Fractional distillation	Batch Batch

tories that could be served from the gas producing areas, Ayres began a study of its use in organic synthesis.

At the beginning both products and markets were unknown factors in the problem. Within several years the first faint rumblings of lacquered automobiles were heard on the highways leading from Detroit.

Fusel oil and fusel oil acetate were the chief commodities visible to meet a potentially large demand for high-boiling solvents in lacquers. The quantity of the byproduct fusel oil available depended on the production of ethyl alcohol, which obviously could not expand at will to satisfy the demand. Apparently, the market factor was in a fair way to being solved if a process for synthetic amyl alcohol could be developed. The investigation which had started on the lower natural-gas hydrocarbons was turned readily to the higher homologues.

The experience of several years has indicated the feasibility of chlorination of the hydrocarbons. Of the methods studied in the laboratory, vaporphase chlorination of pentane above 200 deg. C. was further developed since it could be accomplished without light or catalysts. The yield of primary chlorides is the highest and the formation of unsaturated hydrocarbons the lowest.

Amylene tends to form from the breakdown of amyl chlorides as follows:



In general, higher temperatures favor their formation. Lower temperatures and higher pressure favor their reaction with hydrogen chloride to form amyl chloride.

A successful chlorination procedure must hold the formation of polychlorides to a minimum. These products arise in two ways during the process: First, the reaction of one molecule of pentane with more than one molecule of chlorine, and second, the reaction of chlorine on unsaturated hydrocarbons.

The process finally developed reduces reactions of the first class to a minimum. Chlorine vaporized from the liquid product is introduced continuously into a stream of vaporized pentane, moving at high velocity in order to promote thorough mixing. Twenty parts by weight of pentane is used for every one part of chlorine, a ratio greatly in excess of the theoretical requirements. Temperatures are low during mixing, so that even though several molecules of chlorine may come in contact with one molecule of pentane at the point of entry of chlorine into the stream, reaction is inhibited until after thorough mixing is effected. Probabilities are against the formation of polychlorides after thorough mixing. The mixture is then heated to accelerate reaction.

Amylenes formed as a result of reaction (4) must always be present in the reaction stream, since they cannot be removed from the excess pentane by fractionation. Those formed in the first passage through the reaction return with the unused pentane to chlorination. Formation of the amylenes dichlorides is instantaneous. Even under conditions of chlorination which reduce amylenes formation to a minimum, polychlorides from this cause are far in excess of those formed by multiple contact of chlorine and pentane.

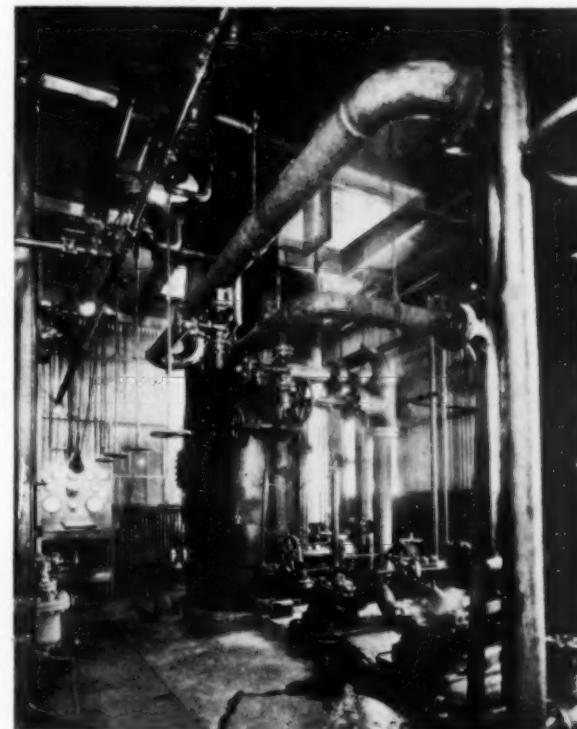
Equipment required for chlorination proved to be of relatively simple design. The high velocity required for mixing chlorine and pentane is obtained by expansion of the pentane through a venturi nozzle into the sides of which chlorine is introduced. The mixed gases pass through a pipe still which is heated by gas. A fraction-

ating column of conventional bubble-cap design removes the excess pentane overhead and delivers a residual crude mixture of chlorinated products. Any amyl chlorides in the pentane returned to the reaction zone chlorinate immediately to polychlorides. Careful fractionation of the excess pentane is thus an obvious prerequisite.

In the original plans, the next operation was the batch fractionation of the residual to remove pentane not entirely removed by the first fractionation, to obtain a finished fraction of the amyl chlorides suitable for hydrolysis, and to leave as a residue polychlorides which are not suitable for hydrolysis.

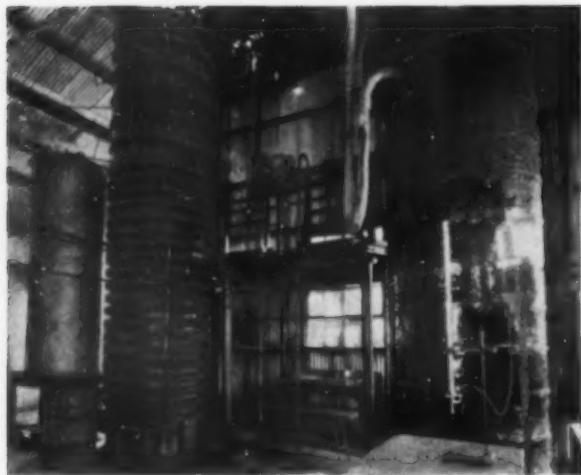
Hydrogen chloride in gaseous mixture with pentane separating from the condensate of the first fractionation is absorbed in the conventional train of silica-ware tourills. The only departure from standard practice is operation at sufficiently high temperatures to prevent condensation of pentane and thus assure its absence in the acid product. Pentane is recovered from gas from the absorbers by compression and condensation. It is returned to the chlorination system. In order to protect compressors from corrosion, this gas is first scrubbed with the caustic brine discharged from hydrolysis.

The practicability of these steps were thoroughly demonstrated in pilot-plant operation, which afforded



Hydrolysis Made a Continuous Operation by Joining Two Tall Digesters and Circulating Between Them, While Maintaining One Full at All Times. The Other, Partly Filled Provides Space for Distillation. Welded Construction and Tube-Turns Used

additional information in regard to correct temperatures and pressures for chlorination and supplied other data for engineering design and operation of the commercial plant. Materials of construction had been selected as a result of investigation in the laboratory and in pilot-plant operation. Copper was chosen for the majority of condensers and heating elements, because of its high heat transfer. Black iron pipe and cast-iron fittings were selected for process lines. Tank steel was used for the larger process vessels. These materials had proved sufficiently resistant to hydrogen chloride gas



Acetylation of Amyl Alcohol. Left to Right: Tank for Feeding Alcohol and Acid to Reaction Kettle, Fractionating Column on Reaction Kettle, Fractionating Column for Rectification of Crude Ester

and pentane to render substitution of more expensive alloys seemingly unwarranted.

Almost from the initiation of operation of the commercial plant, corrosion of process equipment was observed. On a commercial scale accumulations of small quantities of water caused a gradual deterioration at many points in the chlorination system. The chlorine contained a small quantity of moisture. Pentane dissolves a small quantity and commercial shipments often contain free moisture. Pentane recovered from numerous parts of the process for return to chlorination was frequently wet. Cast-iron fittings were the first to be destroyed. Although serious to the extent of interrupting operation and requiring heavy expense for their frequent replacement, this trouble was confined to the failure of the individual part. Subsequent failure of heating elements and condensers threatened the destruction of the entire system. The slightest fissure between the hydrogen chloride mixture on the one side and steam or water on the other quickly opened into a yawning gap that allowed a flood to pour through into the acid stream. Tremendous damage could be done before such leaks were detected.

The remedies applied have been numerous. The evolution of those which have survived the "acid test" can be briefly recounted. The dehydration of fresh pentane from storage, and particularly of the pentane that is wet when recovered, was first attempted in coke-packed towers through which the stream flowed continuously before entering the process. Due to gradual disintegration of the coke and packing of the wetted coke, these towers required frequent cleaning and replacement of the coke. The final remedy has been found in the elements of the process itself. It was observed that the passage of hydrogen chloride gas through apparently dry pentane caused a cloud to form which slowly agglomerated and settled. The precipitated liquid is strong muriatic acid.

At present all new and recovered pentane is so treated in a settling tank. Dry hydrogen chloride gas from the first fractionating column is bubbled through the pentane until the liquid is saturated with the gas. Excess gas passes off to the absorption system. The acidulated pentane stands until the aqueous acid has precipitated and is then pumped into the chlorination system. The acid is drawn from the bottom of the tank. This opera-

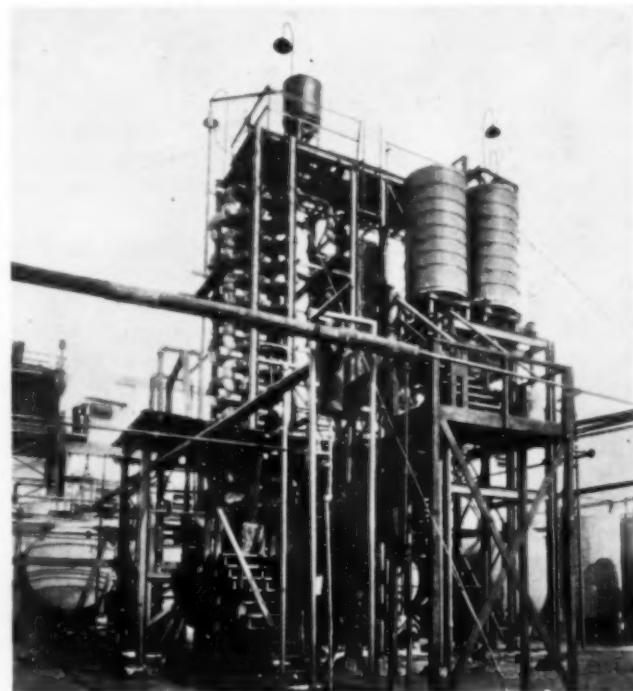
tion is carried out in a steel tank with bottom dished for drainage, at the center of which there is a collection chamber into which the settled acid drains quickly. The bottom of the tank has been made extraordinarily heavy, and periodic inspection forestalls unexpected failure. The collection chamber and drain valves actually bear the brunt of the corrosion and, although replaced with fair frequency, the majority of corrosion troubles have been confined at a point where replacement no longer interrupts operation.

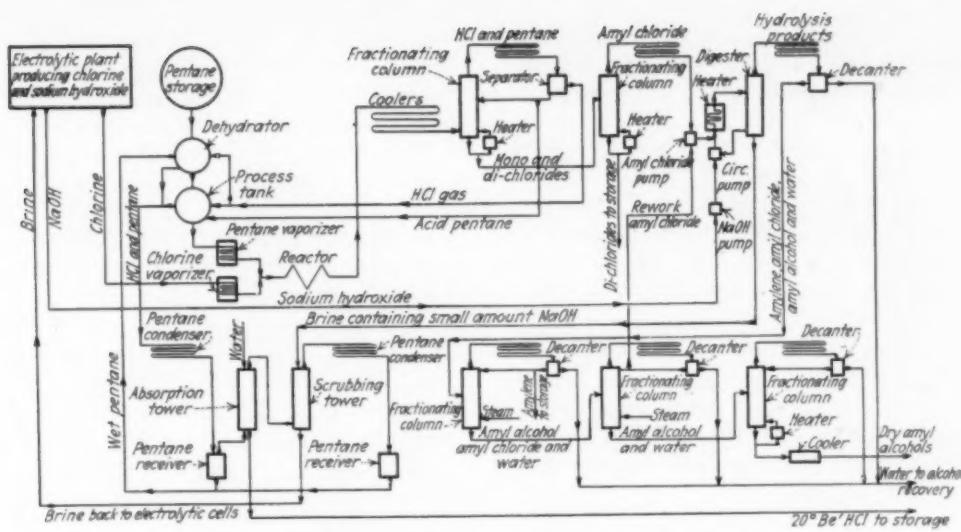
It has been pointed out that failure of condensers was largely responsible for accelerated corrosion in the chlorination system. The original condensers were all jacketed bundles of copper tubes, through which the gaseous and liquid products passed. Jackets held the cooling water under pressure. Originally, the water pressure was in excess of the system pressure, and when leaks developed, water passed inward to mix with the materials being processed. The first attempt to remedy this condition was relief of the pressure of water in the jackets. Leakage was then passed outward and was more readily detected by continuously testing the water for acid. However, serious leakage developed an acid condition in the spray pond and reservoir, which threatened all equipment using it.

This type of condenser has been replaced by condensers of 2-in. Toncan pipe joined together by welding Tube-Turns of this iron at the ends. Cooling is effected by running water over the outside of the pipes. Several of these condensers are manifolded into larger pipes of Toncan iron at opposite ends. They are coupled in with flanges so that there are but two joints per condenser. Removal of a single condenser is readily accomplished. At any time a defective condenser may be quickly blanketed out of operation until a permanent repair can be made.

Toncan iron is now used for all pipe work and for the construction of process vessels when replacements are required. Of the many alloys tried, it has most satisfactorily met the demands for a resistant material at

Absorption of Muriatic Acid From Pentane Gas Is Done in the Conventional Train of Silica-Ware Tourills





**Flow Sheet for Operations of a Plant for the Synthesis
of Amyl Compounds From Pentane**

reasonable cost. Tube-Turns of this alloy have solved the problem of resistant fittings. Welded into the lines, their use has reduced the number of joints in process lines. With screw fittings every joint becomes a point of potential failure and a problem for maintenance.

One experiment which at its inception promised tremendous benefits was the use of the hot gases from the reaction for heating process equipment—in place of steam. Steam heaters had been quite as productive of leaks as had condensers. A minimum of trouble was expected from a system in which the heat would be supplied by the same materials as those being heated. Minor leaks would no longer grow rapidly to major ones, as they do with steam. After prolonged use this scheme was abandoned in favor of steam. Its chief disadvantage was that reaction mixtures remained too long at elevated temperatures and consequently too great quantities of polychlorides resulted. In addition, the work of cleaning heaters increased twofold. In all heaters there is deposition of tarry polymers and free carbon. With steam heating this occurs only on one side of the elements. When heating with the hot gases from the reaction, cleaning is required on both sides of the elements.

Water entering the system has been eliminated from all sources but the liquid chlorine. Close control and co-operation of the manufacturer keep this at a minimum, and with the entrance of water from other sources well controlled, trouble from this source is no longer apparent.

The foregoing steps have reduced interruptions to operations and maintenance expense practically to the vanishing point. Batch rectification of amyl chloride has been replaced by continuous fractionation. After the elimination of excess pentane from the chlorinated products, amyl chloride is taken off continuously as an overhead product from one column, which at the same time delivers as a residual product those polychlorides which are not to be hydrolyzed. The process has become continuous not only in principle but is in fact a continuously operating unit.

The determination of proper procedure for the hydrolysis of mixed amyl chlorides has presented many problems. The tertiary amyl chloride hydrolyzes comparatively rapidly with water. Secondaries react less readily, while primaries are unreactive. Alkaline solutions do not change the rates of these reactions but in

In the cases of the first two chlorides the pressure of an alkaline medium is desirable to neutralize the hydrochloric acid formed. Increasing temperature and intimate colloidal contact accelerate reaction of the first two but do not promote hydrolysis of the primaries.

The reaction of primary chlorides with salts of the fatty acids is more appreciable than the reaction of the secondaries with these salts.

Sodium oleate (U. S. patents 1,691,424-5-6) finally used as a reaction medium is of sufficiently versatile properties to accomplish a dual purpose. First, it forms with the organic materials in the reaction a gel which holds water in suspension, thus promoting the desired intimate contact between water and tertiary and secondary chlorides. Second, it is itself in intimate contact with secondary and primary chlorides, thus accelerating their reaction to amyl oleates. In the presence of caustic soda the oleates hydrolyze readily to the alcohols.

The process is typical of many that are carried out in autoclaves, jacketed or equipped with internal heating elements and agitators. In the design of equipment a departure from the conventional seemed justified, due to the fact that intimate contact of the materials in the reaction can be established without violent agitation and, when once established, separation is slow. Accordingly digesters were built in the form of towers and agitation was provided by means of pumps having a large liquid-handling capacity. These pumps circulate the mass from the bottom to the top of the towers, passing it through steam-jacketed heaters located outside of the digesters. Thus many of the difficulties of agitating material in large vessels under relatively high pressures were avoided and larger reaction vessels could be constructed.

This operation was originally planned as a batch process. A calculated charge of the chlorides, oleate and aqueous caustic soda solution was made up in the digesters and the temperature gradually raised. After a suitable reaction period, the alcohols and amylenes formed in the reaction were distilled off together with any unconverted amyl chlorides. Sodium oleate remained behind, to be used in the next charge. Residual brine was withdrawn and used in scrubbing.

Operation in this manner failed to give the volume of output eventually required. Either a large amount of void space was required in the towers to prevent priming or the rate of distillation was necessarily slow.

when the digesters were charged nearly to capacity. Carry-over of oleate gave emulsion troubles in subsequent distillation, caused losses of soap, and unnecessary expense in recovering it.

Change to continuous operation has been effected by joining two digesters and circulating between the two while maintaining one full at all times. The other, being but partly filled, provides space for distillation. By this arrangement output is largely increased. The void space required in the digester from which distillation takes place is greatly decreased, since the products are being removed continuously as formed. Both caustic soda and amyl chlorides are charged into the equipment continuously to replace the materials used up. Spent brine is removed frequently. The crude product from distillation is freed from amylenes by continuous fractional distillation before final purification.

No amount of hydrolysis or esterification will convert completely the amyl chlorides in the digesters. Consequently, the crude alcohols, after separation from amylenes, contain this unreacted amyl chloride. Its presence is distinctly undesirable in the finished product. Its removal by fractional distillation from crude dry alcohol is not sufficiently complete. It was discovered in batch distillation of wet alcohol that the bulk of the chlorides was removed during the preliminary stages of distillation for removal of water. If there were residual chlorides in the still after water was removed, these hung tenaciously with the alcohol throughout the entire distillation.

The three-component constant boiling mixture of alcohols, chlorides, and water revealed by this discovery is removed continuously in a fractionating column in which the crude is treated continuously with live steam. The steam supplies heat and the requisite quantity of water to form the mixture. The wet crude alcohol likewise is continuously dehydrated in a column from the top of which a constant boiling mixture of alcohol and water is removed. The base product is dry crude alcohol, which is further refined by batch distillation. In this step any

sodium oleate that may occasionally leave the digesters and a small quantity of byproduct diamyl ether are removed. During the distillation, close-boiling fractions of the individual amyl alcohols are obtained when desired.

The tertiary and secondary amyl alcohols tend to decompose, forming amylenes, in the presence of strong acids. Tertiary alcohol is removed from alcohol which is to be acetylated. The secondaries compose too large a portion of the total alcohol product to be discarded for this reason.

Conventional processes for esterification have resulted in extremely low yields when applied to the amyl alcohols. The process of esterification is strictly reversible. To carry it in the desired direction it is customary to remove the water of reaction and any water charged in with the raw materials either by distillation or by employing a strong dehydration agent in sufficient quantities to remove all water from the zone of the reaction. Concentrated sulphuric acid, which frequently is employed as a dehydrating agent, decomposes the amyl alcohols. When water is removed by distillation the unconverted acetic acid is concentrated until it too destroys some of the alcohols.

The procedure employed is designed to reduce such decomposition of alcohols to a minimum. A low concentration of acetic acid in aqueous solution is maintained. Consequently, the concentration of ester in the reaction at any time is small. However, the operation is a continuous one, so that ester is removed as rapidly as it is formed. Output is in excess of that obtainable in equipment of similar size under any other system of operation.

And finally, equipment for acetylation is standard in design, consisting of copper kettle and fractionating column, for the production of crude ester. Both alcohol and acetic acid are charged continuously into the kettle at the same time that a crude ester-alcohol mixture is taken off continuously through the column. A steel kettle and copper fractionating column is employed to rectify batches of the crude.

Experimental Unit for Chlorination of Hydrocarbons. Left to Right: Vaporizers for Chlorine and Hydrocarbon, Control Board, Mixing Chamber, Brick Pipe Still, Condenser and Receiver for Chlorinated Mixture



MARCH OF PROGRESS

IN PROCESS AND EQUIPMENT

◆ IT IS IMPOSSIBLE TO CHARACTERIZE the developments of recent years in any process industry without mentioning the part that improved equipment has played. Improvements have increased efficiency in operation of established methods and have made new processes possible. The urge of competition has demanded more efficient equipment; old machinery has been rendered obsolete by new methods that yield better products at lower costs. Processes for the manufacture of new products generally account for the development of equipment of entirely new design. New materials of construction — most

important of which are the corrosion, abrasion, and heat-resistant alloys—and new methods of construction have played important rôles in the modernization of process industries.

In order to call to the attention of chemical engineers the results that can be expected from available process equipment, *Chem. & Met.* has, with the co-operation of numerous contributors, prepared in the following pages of this issue a symposium on advances that have been made in recent years in the design and construction of unit-operation equipment and their applications in various process industries.

PETROLEUM REFINING PROGRESSES

By JACQUE C. MORRELL

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◆ NUMEROUS IMPROVEMENTS have been made in the petroleum-refining industry in the generation, distribution, and application of heat for ordinary distillation and for cracking. Automatic pressure and temperature controls have been applied to fuel-distributing lines to insure uninterrupted and uniform flow of the fuel, and improvements have been made in fuel-regulating valves; setting of burners; and means of controlling the total, primary, and secondary air used for combustion, which have proved highly useful in the uniform generation of the required quantity of heat with a type of flame most suitable for the heater used.

With the new methods of handling the fuels the use of waste products such as sludges, slop oils, heavy fluxes, and residuals have been made possible, with high efficiency and ease of regulation comparable to those obtained with standard fuels. Improvements in pulverizing machinery and auxiliary equipment have been brought to a degree of perfection that permits the use of coke fines and other low-grade solid fuels even where a fine degree of regulation

is desirable, such as on cracking units. The increased use of forced and induced draft for burning fuels makes the operation of the heater practically independent of atmospheric conditions.

Perhaps the greatest advancement in heating in the petroleum industry has been in the application of radiant heat. The radiant section of the heater has in many installations become the main heating section, supplying up to 80 per cent of the total heat absorbed by the oil, while the so-called convection section, which was the mainstay of the old type of heaters, has been relegated practically to an economizing section to cool the gases leaving the heater and to obtain a higher thermal efficiency. By controlling the flow of oil through the heater, practically any type of heating curve required for the best operating conditions can be obtained, depending upon the results desired—whether the unit is designed for atmospheric distillation or for cracking.

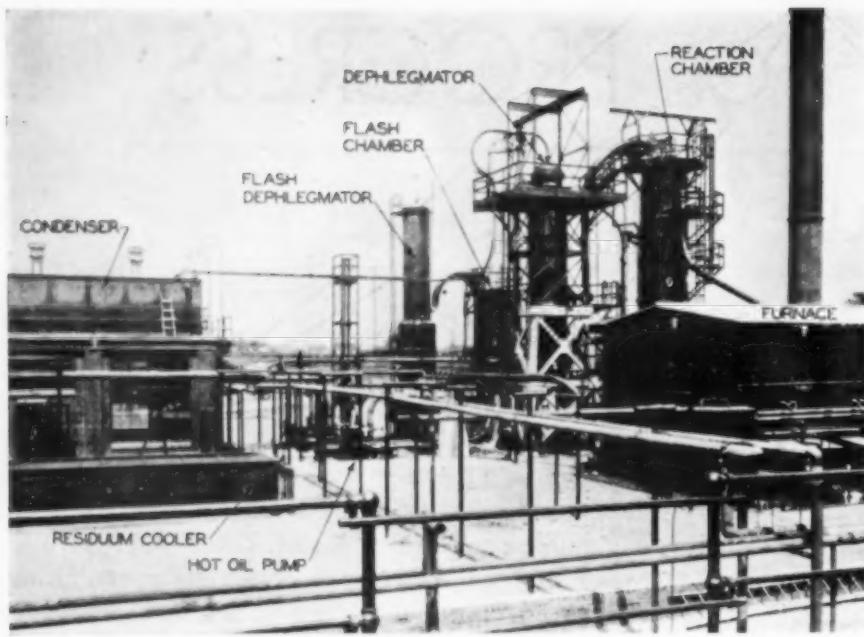
The capacity of the modern heater may exceed 50,000,000 B.t.u. per hour absorbed by the oil and 70,000,000 B.t.u. per hour generated by the fuel. The efficiency of the heat absorbing surfaces in such heater may be from four to five times greater than that of the old convection heaters with absorption rates of approximately 15,000 B.t.u. per hour per

circumferential square foot of heating surface, with less operating difficulties than with the old type of heaters of approximately one-half the absorption rate. Increasing velocities allow greater rate of heat transfer.

Heat exchangers have been developed which will operate satisfactorily under pressures as high as 2,000 lb. per square inch and temperatures of 900 deg. F. or higher. There is a marked advance in the design of such equipment resulting from considerable engineering research in order to eliminate leakage and weakness of parts. These exchangers usually are equipped with a floating head made up in several sections to eliminate expansion strains.

The bubble tower is now generally used for fractionation in petroleum refining, and its design has been brought to a high degree of perfection. Fractionating equipment has been developed to take care of high vacuum operation, especially in the rerunning of treated cracked distillates. This involves large-diameter towers, because of the volume of vapor handled at low pressures, and also requires special care in leveling caps and plates in order to avoid differences in liquid height and also to reduce to a minimum the back pressure through the column.

Stabilizers for the separation of gas and low boiling components from hydrocarbon distillates have come into general use in the petroleum industry during the past five years. Changes in design based upon precise experimental and calculated data permit the separation in a high state of purity of such gases as propane and butane. These gases are



Cracking Unit at the Canton Plant of the Allegheny Arrow Oil Company

finding use for industrial and household purposes.

Absorption systems for the removal of vapors and gases are now being generally used, and may be operated with a high degree of efficiency. These systems usually comprise a compression unit, absorption under pressure with a suitable petroleum fraction, distillation of the absorbed low-boiling hydrocarbon components, and subsequent stabilization of the absorption gasoline. This type of operation has practically displaced all other systems, such as charcoal and low-pressure oil absorption.

New methods have been devised for the removal of hydrogen sulphide from the gases, such as catalytic oxidation methods which convert the hydrogen sulphide into sulphur, thus obtaining a valuable byproduct, and more recently special absorption agents having a weak basic action and showing a high degree of solubility for hydrogen sulphide, such as triethanolamine have been used with marked success.

Modifications in cracking processes have been directed mainly to increasing the yields and anti-knock quality of motor fuel, with corresponding reduction in gas losses. The modern cracking process may be operated to produce high yields of gasoline having anti-knock quality superior to ethyl gasoline with relatively low gas losses, producing at the same time marketable fuel oils of low suspended carbon content. In operations wherein fuel oil is one of the products some modification of flashing is employed. Notable among the improvements has been the production of high anti-knock gasolines from charging stocks such as Pennsylvania fuel-oil distillates and similar charging stocks with high total liquid recoveries and gasoline production.

Progress has been made in the de-

velopment and use of automatic controls of temperature, pressure, and flow in refining processes to increase yields and smoothness of operation. New apparatus has been designed particularly for automatic temperature control which will cope with the severe conditions encountered in refining with regard to time lag and sensitivity. Instruments have been developed which will reverse their action as soon as the trend of temperature away from the normal has been arrested to eliminate overrunning and consequent saw-toothed curves characteristic of the older type of instruments. Combinations of temperature-control instruments also have been set up to act on the process as a whole rather than on independent elements of it, thus forming a protective interlocking control system.

With a more thorough understanding of the chemistry of refining, petroleum distillates from any source, whether straight-run or cracked, may be refined to meet all specifications with regard to color, stability, odor, doctor test, and gum and sulphur content.

Reactions of sweetening and their application to practice are now better understood. As a result, sweetening agents other than the conventional "doctor solution" have been developed.

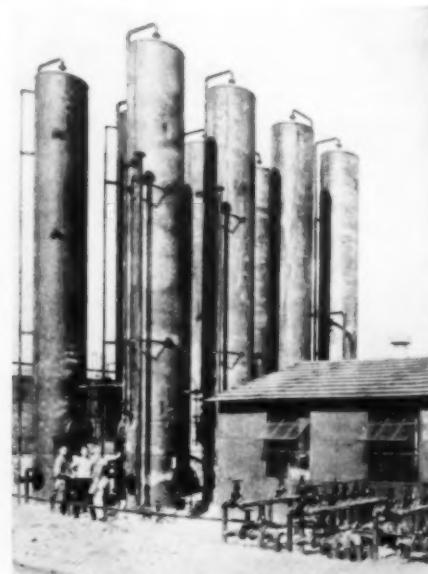
Low-temperature treatment of cracked distillates, primarily for the purpose of desulphurization, has resulted in a reduction of solution and polymerization losses. Extensive improvements have been made in the recovery and regeneration of acid sludges and plumbite sludges, including lead sulphite, for sweetening, thus reducing the cost of treating reagents.

Stabilizers have been developed to prevent depreciation of cracked gasoline in storage with respect to color, gum formation, and reduction in knock-rating.

Distillation agents have been developed which improve the color and stability of gasoline distillates and reduce their gum content. Treatment of cracked distillates in the vapor phase to produce finished products direct from the cracking unit is coming into general use. These include treatment of the vapors with adsorptive earths, special polymerizing agents, and chemical reagents.

Improvements in the design of treating equipment directed to more efficient mixing, making use of orifice and specially designed mechanical mixers; and special arrangements for complete removal of sludges have increased the efficiency of treating equipment, reduced the reagent requirements, and improved the product. Automatic control equipment has been instrumental also in obtaining improved operation of the treating plant. The present tendency in the art of refining cracked distillates

Left—Gas Absorption Plant. Right—Continuous Straight-Run and Pressure Distillation Treating Plant



is to combine the cracking and treating operations so as to produce a finished gasoline product direct from the cracking process.

Successful developments in chamber linings comprising numerous concrete, cementitious, and ceramic materials primarily to protect cracking vessels against corrosion have been accomplished. These include ganister linings with structural steel supporting members and unsupported relatively thin linings made up of mixtures of sodium silicate, quartz sand, furnace cements, and the like. Alloy-steel linings also have been developed. Chrome and chromium-nickel alloys have been used for fabricating tubing to reduce corrosion in cracking stills.

Much work has been done in the development of hydrogenation processes with the objects of producing gasoline from heavier oils.

Derivatives from vegetable oils are used to some extent to affect beneficially the surface tension and oiliness of lubricating oils. The present tendency is toward the production of equilibrium viscosity lubricating oils and those which in general have a flat viscosity curve as a function of temperature. These include oils of a synthetic or polymerized character. The use of centrifugal separators for the removal of wax is now widespread and a more scientific application of refrigeration permits the production of lubricating oils of any desired degree of cold test.

DESIGNING NATURAL GAS PIPE LINES

◆ THE GROSS COST OF A PIPE line, for either natural gas, crude oil, or refined products of petroleum, as compared with the transmission capacity, of course, determines the capital charge that must be borne by each unit of product transported. Especially with natural gas, the best way in which to get a favorable ratio between capital cost and capacity is to design the system for high-compression pressures. The upper limit which it is practicable to use in transmission, however, depends upon the character of the pipe line used and the practicability of securing bottle-tight joints without prohibitive expense.

In designing high-pressure pipe lines the use of an alloy-steel pipe with alloy-steel welded joints for most of the assembly has been demonstrated to be entirely practicable. Such pipe, of course, costs more per ton, but this disadvantage is often more than offset by the possibility of safe use of a thinner-walled pipe than would be practicable with ordinary carbon steel. The lower cost at the producer's mill per mile of length of such pipe is not the only

advantage attending use of alloy steel. The cost of transportation to the job, especially hauling over rough country beyond the nearest railroad contact; the cost of handling it in the trench; and other like advantages are of importance.

The cost of welding alloy-steel pipe is not enough more than the welding expense with ordinary steel to be a serious deterrent if proper welding rod and welding technique are used. Such welded joints, and the necessary coupling joints to provide for slip and flexibility, can all be made bottle-tight for any pressures which it is practicable to use in transmission. The real limit on the pressure at recompression stations is caused by the greater cost of pumping engines and fuel or power for their operation when working at extremely high pressures.

A careful and detailed engineering calculation is required for each particular line to determine what point in the

WATER-GAS PROCESS MECHANIZED

◆ ENTIRELY NEW DESIGNS IN gas-making equipment have been developed during the past few years, placing the water-gas process on a highly mechanized basis almost undreamed of at the beginning of the period. Automatic charging, automatic control of the cycle operations, and automatic clinker discharge have combined to change water-gas making from an intermittent, laborious, and none too efficient task into its present high state of development.

Both the control and the clinker-discharge developments have gained a large part of their advantage simply through the shortening of lost time in operation or for ash removal. By this



On Wide River Crossings Pipe Was Welded Into Line, Joint by Joint

pressure range, up to 1,000 lb. or more, will give the optimum over-all cost, including operating expense and capital charge under the conditions of load factor which it is anticipated will apply to the line in question. Only within the last few years has the proper calculation of these design features been thoroughly understood; but it is now carefully applied by pipe-line companies in the interest of low transmission costs. As a consequence in many cases it is estimated that gas is being handled for not to exceed 2.5 cents per 1,000 cu.ft. per hundred miles of transmission distance. Only because of such low over-all cost has it been possible to develop the modern gas-handling scheme that has spread natural gas over almost all of the United States through lines ranging up to 1,000 miles in length. In most of this work, alloy-steel pipe has not been used, but the modern trend is decidedly in this direction for certain types of high-pressure systems.

means the capacity of a modern machine can be made much higher without any other change in condition of operation. Incidentally, however, the new designs involved achieve a superior uniformity in fire control in a machine and hence a greater uniformity of gas-making performance. Because of the largely increased capacity of a given machine, the capital charges per unit of gas made are correspondingly reduced. This saving is several times as much as the increased capital charge per year incident to the more elaborate mechanical equipment required. Thus there is a large net gain.

Not only has the labor requirement in man-hours per machine-day been reduced but the character of the labor involved has been radically changed. Introduction of the fuel and removal of the ashes by automatic equipment has taken the heavy manual labor entirely out of this part of the works. Power-driven chargers, clinker crushers, and

ash-handling facilities have converted the gas maker's job almost into a white-collar status. As a consequence a superior type of operator is naturally attracted to the jobs and men can be chosen on the basis of their mental capacity, not merely because of their brawn and ability to withstand bad working conditions.

Changes in the type of fuel used in water-gas making also have been made possible by other features of improved design. Bituminous coal for solid fuel

and "bunker C" grade of heavy fuel oil for carbureting are now acceptable raw materials. Accurate process control incident to automatic operation has been only a part of the requirement to permit these changes to lower-cost fuels. Modified generator and carburetor construction also have been involved. A pier is often placed in the center of the fire; carburetors are run checkerless; and back-run or other modified connections are made to permit the newer type of operating cycles.

forcing them into the digester under pressure. Air is recirculated through a fan, from the digester to the filling-head. Processes have been developed for conserving heat and sulphur dioxide. Circulating systems are being introduced for increasing the uniformity of the contents of the digester and reducing steam consumption. Non-uniformity is one of the most serious problems of the pulp-mill engineer.

Two-stage bleaching is becoming more and more popular and is replacing the older one-stage process. High consistency has proved to have certain definite advantages of decreased amount of bleach and steam usage, and improved color. The two-stage process is opening to kraft pulp wider fields of utility. The trend is toward continuous operation as applied to the unit operations of filtration, mixing, and washing. The rod mill, a rotating drum containing heavy iron bars that roll and skid over one another, has been adapted to the beating and refining of pulp. During the past year, this piece of equipment has been successfully introduced into the sulphite mill. It is economical in the consumption of power and is continuous and almost wholly automatic in operation.

Changes in paper machines have made it possible to make wider paper, and at a greater rate of speed. A new machine now available makes 190-in. book paper at 1,000 ft. per minute, and newsprint-paper machines have been modified to make much wider rolls. Some machines are designed to turn out 1,500 ft. of paper per minute. Decided progress has been made in the ease of changing fourdrinier wire. Electric drives on the machines and roller bearings on the fourdrinier have been more or less generally introduced. Improved mechanical water removal at the wet end and the continuous centrifugal removal of dirt, slivers, and other foreign particles in the pulp stream ahead of the paper machine are other improvements. One new type of paper machine that has been installed in a few mills, differs from the machine in general use, in that it does not have the long wire form on the fourdrinier and operates at much higher speeds.

PAPER MILL EFFICIENCY INCREASED

◆ ALTHOUGH THE PULP AND paper industry at one time was reluctant to put its reliance on chemical engineering, it is now taking advantage of this branch of science. The result is that numerous changes are constantly being made in the design and construction of process equipment in every department of the industry. These modifications have resulted in improved quality of product and increased economy of production.

After ignoring for years corrosion losses, which in many sulphite mills have been between \$50,000 and \$75,000 annually, the industry has now become corrosion-conscious. In an effort to reduce this bill, the new alloys and other materials of construction are being adopted for the construction of equipment. In the sulphite mill the 18-8 chromium-nickel ferrous alloy has been adopted.

The inherent hardness and corrosion resistance of chromium plate is making this material immensely popular among pulp and paper-mill engineers. Important applications include condenser and evaporator tubing, screen plates, suction-box plates and rollers, friction calender rolls, steel-engraved embossing rolls and plates, copper-engraved printing rolls, knives, and slitters.

The hard facing of parts of equipment by the use of special alloys has resulted in longer life of equipment; hence fewer replacements, and inasmuch as the active surfaces stay in better condition, the machine is likely to operate more efficiently than with ordinary tools.

In addition to these materials, carbon is now used as a material of construction where corrosion and erosion are troublesome.

New equipment has been designed to perform a job more efficiently and other equipment has been modified with the same purpose in mind. For handling pulpwood, the largest material in bulk and money value that is handled in the mill, the power rake was developed two years ago. It stores and reclaims with less danger to workmen and at lower costs.

In and about the sulphite digester, many changes have been made. Wood and chips charged into the digester are weighed and the slush pulp is now measured. One system, which has been in use in this country for only one year, claims at least a 20 per cent increase in chips charged into the digester, with accompanying savings in reagents and increase in production per digester. Chips are introduced into special filling-heads where they meet a blast of air,

Electric Power Rake for Storing and Reclaiming Pulpwood Works on the Drag-Line Principle



SOAP TECHNOLOGY MEETS CHANGED MARKETS

By OSCAR H. WURSTER

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◆ SOAP MAKING IS CARRIED out almost exclusively by the saponification of fats and oils and their fatty acids in large batches in open kettles at atmospheric pressure. The various methods proposed from time to time for saponification under pressure and for continuous processes have not been generally adopted. In this basic soap-making process there have been improvements in material handling and in the design of equipment and plants. Caustic soda is now received at most plants in solution. Facilities for receiving, handling, and refining fats and oils are improved. Monel metal construction for lining soap kettles and for kettle coils and fittings is used for the highest qualities of soaps. In new plants the proper ventilation of the kettle house has received special attention.

Soap, after finishing in the kettle, goes through various processes and then on the market as laundry or household bars, toilet bars, chips, flakes, powder, paste and liquid. Each of these products has its own method of manufacture and there are numerous modifications in each group.

Bar soap is the oldest of these forms, and there has been little change in the essential operations involved except in the general adoption of cooling and drying machines for toilet soaps and greatly improved presses and wrapping machines. Some years ago there was considerable interest and activity in the development of continuous bar molding machines which would take the hot liquid soap from the kettle or crutcher, form and cool it in molds, and deliver the finished bar ready for wrapping. None of these machines has been successfully developed. In Europe soap is cooled in thin slabs in chilling presses, but this equipment has not found favor in American plants.

Much of the increased production of soap has been in the form of chips, flakes, and granular or globular powders. The most marked improvements in processes have centered around installations for these products. Flake soap is made by passing a milled chip through mills with water-cooled steel rolls which roll the flakes to a thickness of 0.002 to 0.005 in. and polish the surface. This gives a thin, lustrous, and transparent flake of pleasing appearance. The milling, weighing, packaging, and sealing are entirely automatic.

Soap powders containing from about 12 to 50 per cent soap and high percentages of sodium carbonate and moisture have been produced for many years and retain their popularity for the kinds of work to which they are best suited. Spray processes for producing soap powder, as in the drawing, are displacing the older and more cumbersome methods, such as floor drying or drying on chilling rolls, with subsequent grinding in either case. The hot liquid mixture of soap, soda ash, and water is sprayed into the top of a tower by atomizers or mechanical devices. While the finely sprayed particles are dropping through the tower the soda ash in the mixture takes up the moisture as water of crystallization, and the granules cool and harden. The cooling is facilitated by air circulation and usually without special conditioning of the air. The tower may be operated at atmospheric pressure and temperature. The physical form of the finished powder is dependent on the spraying conditions and usually is of a uniformly fine granular appearance.

In the production of this type of soap powder the removal of moisture is not a major consideration. The moisture, as pointed out above, is taken up by the sodium carbonate. There is some evaporation in the tower and this assists in the cooling. The spray process of

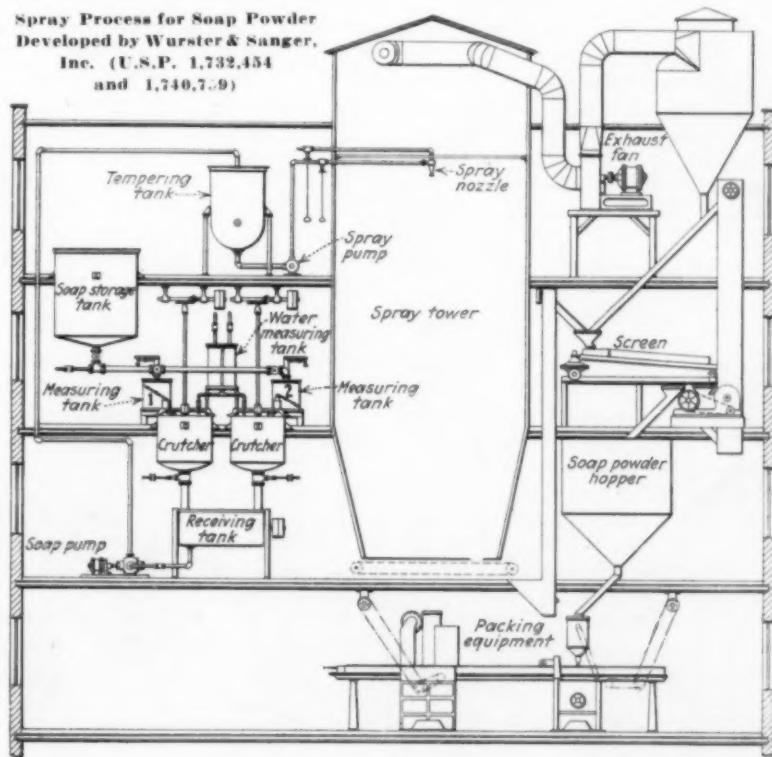
making soap powder simplifies the operation, does away with working in a dusty atmosphere, and reduces power and labor costs.

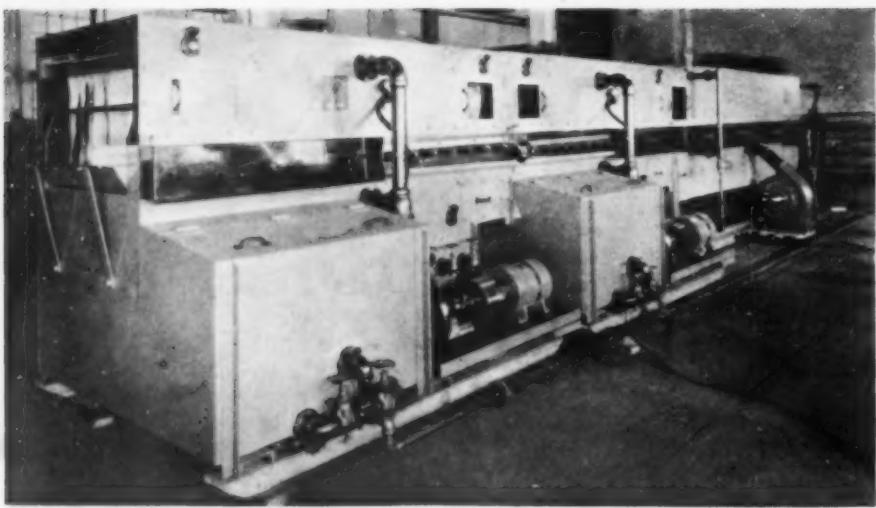
The use of soap in powdered, granulated, or globular form, both as pure soap and soap in admixture with other chemicals, has greatly increased, and processes have been developed to produce these products in a more desirable form or in a more economical manner. The older method is to grind pure soap chips to granular form, and if the addition of some other ingredient is desired, the mixing takes place either before or after grinding the soap. Among the chemicals used in admixture with powdered soap are those with mild bleaching properties, such as perborates, and those with special detergent properties, as trisodium phosphate.

Pure soap and soap containing silicate of soda are now sprayed on an extensive scale. These processes involve the removal of considerable moisture and therefore are carried out at relatively high temperature. The air or other gases used for drying are heated. The spraying is variously carried out to produce the desired product, either with high pressure and temperature at the spray nozzles or by means of a suitable mechanical device for breaking up the material. The finished product in some processes is in the form of small, thin-walled globules and in others is in a uniformly granular form.

From the process standpoint the development of the various spray processes for making soap products has been the most interesting in this industry in recent years. With the increased consumption of these products further developments in this direction may be expected.

Spray Process for Soap Powder
Developed by Wurster & Sanger,
Inc. (U.S.P. 1,732,454
and 1,740,759)





Medium Duty Washing, Rinsing and Drying Machine

ELECTROPLATING MADE AUTOMATIC

By A. K. GRAHAM

Department of Chemistry
University of Pennsylvania

◆ IT HAS ONLY BEEN WITH the introduction of automatic electroplating equipment within the last decade that chemical engineering has been applied to the electroplating industry, and this application has resulted in a vastly superior quality of product, increased production, and lowered costs. Prior to this time, vat and mechanical barrel plating in batch operation was universally practiced, with its inherent limitations of the variable human element of labor and the difficulty of controlling the many plating variables involved in turning out a finished product.

The types of automatic electroplating equipment have become well standardized, although modification of design in the future would not necessarily be surprising. Mechanical barrel plating equipment, for example, may represent the best from the standpoint of material and construction, but little improvement in design has been made since the introduction of the horizontal type of barrel.

The so-called "semi-automatic" installation consists of a conveying mechanism, with variable speed, for moving the work through the solution during plating from point of loading to point of unloading. The unit can be applied to a tank of almost any size and the speed and current density varied to give the desired volume of work or weight of deposit.

Completely automatic equipment consists of a conveying mechanism, not only for moving the work through each individual operation of the plating cycle but also for transferring racked work from one operation to another. The manner

of accomplishing the mechanical features involved vary, of course, with different manufacturers. The prime essentials in their design and construction are, according to one builder: (1) A mechanically perfect transfer which operates quickly enough to avoid oxidation and without excess swaying of the racks. (2) A flexible machine where changes in process can be effected with scarcely any delay and very little expense. (3) A driving mechanism giving variable speeds so that the period of plating time can be changed instantly. (4) Electrical contacts designed to take any quantity of current that may be necessary. (5) A machine that will operate with minimum upkeep expense.

The height and width of a full automatic installation will vary with the work being plated, the manner of racking, and the make of machine. The length depends upon the number of operations in the complete plating cycle, as well as the length of tanks required for individual operations. This latter factor depends upon the speed of the conveyor and the time required for the operations.

Since the cost of an installation varies directly with the number of operations in the plating cycle, the number usually is reduced to the minimum that will still give the quality of plate and weight of coating demanded. The selection of the proper plating cycle, therefore, is the most important single factor in construction of a full-automatic machine, for both the cost of the installation and the performance depend upon it. Furthermore, the cycle is the one chemical engineering feature that is continually subject to change, as research and experience make improvement possible and as the conditions to be met are varied.

Semi- and full-automatic installations are always justified where work of a similar nature is to be processed in sufficient quantity to keep the equipment operating at capacity and provided the reduction in required floor

space, time and labor; the increased production, simplified control, and improved quality make it economically possible to carry the investment. Most large - scale continuous industrial methods show sufficient saving when compared with batch methods to justify the improvement, and the electroplating field is no exception, as is amply proved by the numerous automatic installations in successful operation.

Aside from the subject of electroplating apparatus much can be said about the auxiliary equipment involved in any modern installation. Motor-generator sets with field rheostat control for individual plating solutions has become quite general. Low-voltage generators and control rheostats have been greatly improved, the former with regard to current capacity, commutation, and the tendency to overheat when operated above their rated capacity. The latter in respect to resistance material and design.

Emphasis on improved quality has led to frequent filtration of still plating solutions and continuous filtration on automatic installations. Small portable bag filters or presses are commonly used for intermittent filtration. Large presses of standard design with motor-driven centrifugal pumps are the rule for continuous filtration. The usual procedure has been to pump the solution from the bottom of the tank through the filter and then to return the filtrate to the top of the tank. Recently this has been reversed, with good results. The advantage lies in the fact that, once the solution has been clarified, the fine suspended matter that would ordinarily affect the quality of plate is more quickly removed by floating off at the top.

Various combinations involving automatic Ph control and purification of solutions with continuous filtration have been attempted in the past, and with the introduction of low Ph nickel solutions, further developments in this direction are expected to overcome much of the difficulty due to pitting associated with this type of solution.

Automatic temperature control and chemical control of plating operations are becoming universal and have played no small part in the steady improvement in quality of products.

The ease with which unit equipment for metal washing, drying, and enameling can be incorporated as part of full-automatic installations has led to their use in a number of installations. The installation at the National Cash Register Company, Dayton, Ohio, is an excellent example of the application of standard material-handling equipment to serve the needs of the metal finishing departments. Throughout, the tendency has been to use standard unit equipment in electroplating installations, resorting to the design and construction of special machinery only where standard equipment could not be used.

ECONOMIES MADE IN RUBBER INDUSTRY

◆ RECENT YEARS HAVE SEEN a continuous rearrangement of the plants producing tires and inner tubes. Straight-line flow of materials and coordination of succeeding process operations have been further applied until each step in the production dovetails into the next. Installation of automatic materials-handling equipment has made this possible. Numerous economies have resulted. Reduction in the number of workmen, a saving in floor space of about 30 per cent, a lowering in the number of defects, and a large decrease in the number of accidents are among the most important.

Tire manufacturers depend mainly upon chain and belt conveyors, but use many other types in addition. A special truck has been designed and constructed which serves as a temporary storage for 200 treads, in order to have a reserve supply of these strips for the tire-builders. The truck resembles in appearance a large mobile book. An electric truck used in paper plants for handling rolls of paper has been modified and adapted by the rubber industry, which uses it for handling rolls of rubberized fabric.

As a result of the adoption of materials-handling equipment, the process of building a tire has been entirely changed. The flat hand-shaped tire is constructed by a single workman in one-tenth of the time formerly required for each tire. The building of rubber boots likewise has been changed to a one-man job by the use of conveyors, which has reduced the time required.

In rubberized fabric making, the use of cord fabric in place of woven has increased efficiency. In the same field, the engineers have found that by placing the calenders in trains, the several layers of rubber can be put together more satisfactorily and in less time.

At present, many plants are using in their tire storage departments a battery of large heaters in which the vulcanizing is done. Each tire is placed in a heavy mold which is put into the vulcanizing pit. "Watch cases," automatic individual tire-vulcanizing units, are now being substituted for the multiple type, and it is expected that economies will result. The individual vulcanizing units also are replacing the older multiple type for inner tubes and, as in the tire department, this marks an important stride in the development of the rubber industry.

Rubber garden hose is now extruded instead of being built up by wrapping around a mandrel. Consequently, it is practical to make much longer lengths than formerly.

During the past few years the Banbury internal mixer has become generally adopted in the industry. One of its principal advantages over the former method of mixing is in the larger batch of materials that can be handled in one operation.

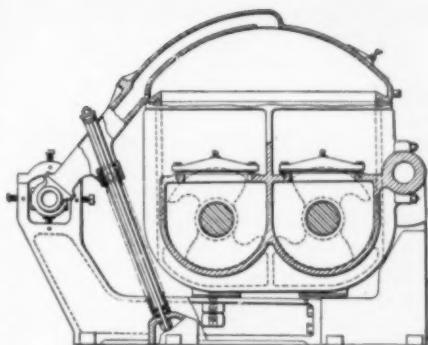
Last, but not least, is the very interesting and economically important development in the field of rubber-covered wire. One of the largest users of this insulated wire has developed a process for continuous vulcanization of a rubber covering on a copper wire. Previously, the covering was extruded on the wire, and comparatively short lengths of it were vulcanized in pans, the soft rubber being protected by an inert powdered material.

IMPROVED WORKING OF PLASTIC MATERIALS

◆ BECAUSE THE VARIOUS compounds included in the concept "plastics" are primarily produced in equipment adapted either from their own manufacturing tradition or from other chemical engineering operations, the principal progress at present is concerned with the subsequent phases of manufacture.

Compounding and mixing play an important part in all plastics manufacture. In the case of pyroxylin-base materials, improvements in the vacuum mixer have facilitated solvent removal after admixture of camphor. Originally an adaptation from the bakery dough mixer, it is now equipped with sturdy blades and rugged, closely fitted bearings. Because the vacuum hood must be removable while the vessel is tilted for dumping, the movement of these heavy parts has received special attention. In the design shown in the drawing, the hood is a unified movable section with a single adjustment in front to seal for each batch. The mixer itself also has been improved to allow a single manipulation to tilt it forward for discharge. Hydraulic power has dispensed with counterweights and generally simplified the apparatus. Because the laminated-glass industry has greatly straitened the demands on pyroxylin plastics, the mixing chamber and blades are now sheathed in stainless steel to give a more marketable product.

The Banbury mixer, which is finding increased reception in the rubber industry, is now also becoming useful in manufacture of resinous plastics. The "curing" and compounding (with wood flour and pigment) usually are carried out in a series of heating, rolling, and mixing operations, which the Banbury mixer combines in a much shorter time at decreased power per unit output. There probably will be other uses for



Side View of Cavagnaro-Loomis 100 Gal. Vacuum Mixer for Solvent Extraction During Mastication

this heavy-duty equipment in other plastics industries.

Heated rolls are necessary equipment in pyroxylin-plastics production but they also are doing service now in "curing" resinous plastics by converting them to their secondary stage with heat and pressure. Incidentally, pyroxylin lacquers passed through Farrell rolls receive a desirable high luster.

In the molding of resinous plastics (really the final stage of chemical reaction), much design work is still in progress, but not yet at a point where results can be reported. Injection of the material into a mold, instead of compression molding, is one outstanding case. The possibilities are economy in design and size of equipment and in material used.

CERAMIC INDUSTRIES MODERNIZE

◆ DESIGN HAS BECOME AN active topic in the ceramic industries. Its most important manifestation has been in the improvement of firing methods and equipment, particularly in the tunnel kiln. Such kilns have penetrated into the enamel, tableware, sanitary ware, electrical porcelain, firebrick, and high-temperature-refractory fields. Thermal efficiency has been improved and firing time reduced. Manufactured gas has been used, but infrequently; natural gas is spreading in some sections; and stoker firing has been applied successfully. Continuous electric kilns have gained importance in the porcelain-enamel industry. Continuous kilns of all kinds have been built larger than ever before.

An interesting new form of kiln has been evolved which does away with the kiln car, substituting for it a simple refractory platform which is carried through the kiln in a manner reminiscent of certain glass lehrs. Side rails lift at intervals and carry the platforms forward a short distance, whereupon the rails are lowered and retracted, ready

to carry the ware forward again on the next movement.

Mechanical forming has been a field for new and better methods. Larger and more powerful presses, both mechanical and hydraulic, have been designed and put into service. This has been particularly the case in the refractories industry, where fireclay, high alumina, chrome, magnesite, and even silica brick are being produced by this method.

Improvements in other equipment lines have also been made. Continuous dryers have come into use. Materials-handling methods have been brought up to date in many plants. A notable tendency seems to be toward the use of overhead rail equipment, which presents the advantage of being out of the way, although making very large storage capacity available.

An outstanding development in the feldspar field has been the introduction of what is called a dia-magnetic separator which has a very high intensity field capable of removing materials from feldspar which are so faintly magnetic that their separation by this means was formerly considered impossible. Tourmaline, garnet, biotite, and even muscovite are said to be separable. The machine consists of a series of small laminated rotors placed near the pole pieces of two very powerful magnets. As the material is cascaded over the rotors by means of a series of chutes, the various contaminating minerals are pulled from the stream by the rotors and dropped into tailings chutes.

CEMENT GRINDING IMPROVES

◆ A RECENT BENEFICIAL trend in the grinding practice of the portland cement industry is evident from the fact that a number of plants have gone to the close-circuiting of grinding equipment to reduce power consumption and increase the fineness of the product. The causes have included a desire for greater economy and the need for a finer degree of grinding to meet the increasing demands for "super" cement. The directions in which this work has carried have been two. In wet-process plants, raw materials have been ground in wet mills, close-circuited with Dorr classifiers. In dry-process plants, as well as in the grinding of the finished cement in wet plants, the mills have been close-circuited with reverse-current air separators of the Hardinge type, or with externally-driven air separators of the Raymond, Gayco and Sturtevant types.

The first installation of Dorr classifiers was made at the Davenport

(Iowa) plant of the Dewey Portland Company during the early months of 1930. The results are said to have exceeded expectations, increasing output per mill-hour from 70 to 167 bbl. Two rake classifiers are close-circuited with the primary compartments of two mills. The oversize returns by gravity to the primary compartments while the classifier overflow goes to a sump. Two bowl classifiers are operated in close circuit with the secondary compartments. The oversize in this case returns to the secondary compartments while the overflow passes to the same sump which receives the product of the primary classifiers. The finished grind is then thickened to conventional consistency in a Dorr traction thickener. After correction of the lime content,

size for the mill, total grinding power on this hard clinker was only about 4.97 kw.-hr. per barrel. Before this grinding system was installed, the plant used a two-stage ball- and tube-mill set-up, requiring 7 kw.hr. per barrel of cement which was only 85 per cent through 200 mesh. This represents a power saving of 29 per cent, at a considerable improvement in fineness.

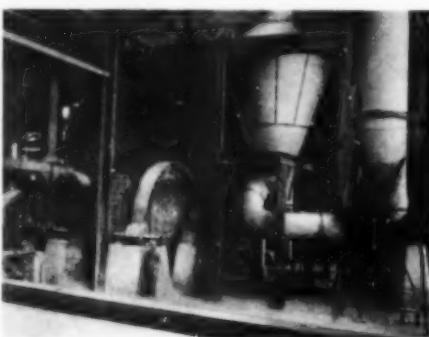
VARIED PROGRESS IN HEAVY ACIDS

◆ EACH OF THE THREE HEAVY acids, nitric, hydrochloric, and sulphuric, has benefited to a greater or lesser extent from improved practice within recent years. The most radical change has come about in the nitric acid industry, where the ammonia oxidation process has very nearly displaced the older Chili nitrate and sulphuric-acid method. Only in the case of a few plants, chiefly those that need the byproduct niter cake, is the old process still in use.

Development of low-cost synthetic ammonia has been the primary cause for the swing to ammonia oxidation. In the United States, the process used is that of pressure oxidation, the mixed ammonia and air being compressed prior to the passage through the platinum catalyst. This permits the use of less platinum than would be required were the oxidation to take place at atmospheric pressure. On the other hand, it is the claim of Giacomo Fauser, Italian engineer, who has abandoned the use of pressure for the catalysis, that the useful life of the platinum is reduced by the added intensity of operation. In the Fauser process the compression of the gases takes place after oxidation to NO. The reason for this course is found in the claim that the conversion percentage is considerably greater than it is at a higher pressure. The difficulties incident to compression of the nitrous gases prior to absorption have been overcome through the use of suitable chrome alloys for the turbo-compressors.

A further difference exists between the American and European systems. In American plants, the absorption is carried out in packed alloy-steel towers, whereas the Fauser process is based on the use of a cascade of unpacked alloy-steel absorption cylinders, which, it is claimed, offer less resistance, give better cooling, and improve the absorption generally.

Present methods in making hydrochloric acid are tied up to a certain extent with the change in production of nitric acid, as well as with local market conditions for niter cake and salt cake.



Hardinge Close-Circuit Mill for Cement Clinker

the slurry is dewatered on American disk filters.

Results have included an increased mill capacity averaging over 135 per cent. The average unit power consumption for the wet grinding has been reduced from 5.5 to 3.01 kw.-hr. per barrel, of which about 25 per cent is required to operate the circulating pumps, classifiers and thickener. The fineness of grinding also has materially improved: where in 1929 the product was 89 per cent through 200 mesh, by the new method it shows better than 97 per cent through 200 mesh. The capacity of the kilns consequently has increased 17 per cent and the strength of the finished cement is considerably higher.

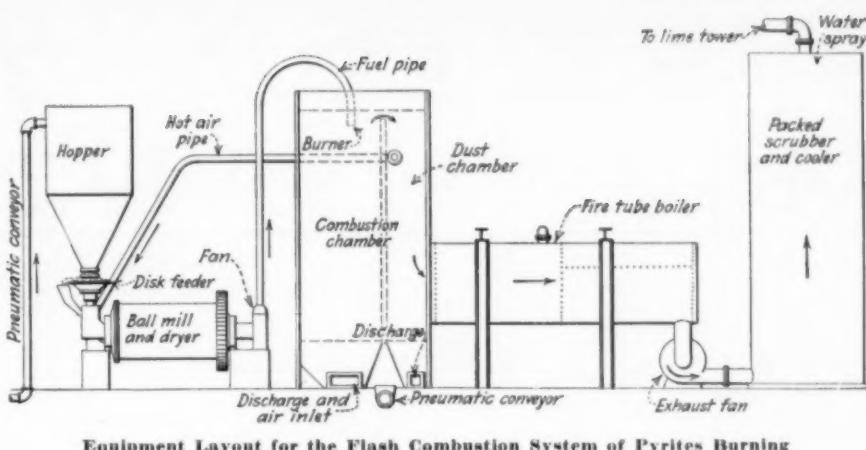
The case for dry grinding in close circuit is equally encouraging, although not as many data are available. Such an installation, made by the Hardinge Company, appears in the accompanying view. A conical ball mill is close circuited with a reverse-current air separator, which increases the mill capacity from 15 to 25 per cent. In a typical Hardinge installation, a 10-ft.-diameter mill, 66 in. long, working on hard, overburnt, dry-process clinker produced 75 bbl. per hour, 90 per cent through 200 mesh, at a power consumption of 4.75 kw.-hr. per barrel. Including the power required for the rolls used to reduce the kiln clinker to $\frac{1}{4}$ -in.

Since an actual shortage of niter cake has now existed in the United States for several years, it is used only to a very much smaller extent than formerly for making HCl. The development of greatest importance in the old niter cake and salt process is the Laury furnace, a rotating cylinder about 5 ft. in diameter and 20 ft. long, in which the mixed raw materials are fused to produce salt cake and HCl. These are being used in at least one plant, and installed in another. Other production is chiefly byproduct in origin. Where there is a surplus of chlorine and hydrogen in the electrolytic process for NaOH, it has become the practice to burn the chlorine with hydrogen in fused-silica cylinders, and to absorb the product in horizontal fused-silica vessels of S-bend shape which are connected in series, one above the other. A method which has been installed on the Pacific coast passes any chlorine in excess of market requirements through a gas producer, where it combines with the hydrogen so produced. The resultant HCl is absorbed in fused silica equipment. Acid which is given off as a by-product of certain chlorinations is also on the market.

A change in the relative positions of contact and chamber processes for sulphuric acid has taken place in recent years. Where the contact process was formerly a luxury, usable only where the object was the production of strong acid, it has now reached a point, largely through the advent of satisfactory vanadium catalysts, where it can compete on a basis of substantially equal construction cost with the chamber process. This means that, where there is need for stronger acid or where it may be necessary to market surplus production, chamber plants are not likely to be built unless certain of the intensive systems can be made more attractive from the standpoint of investment cost.

Probably the greatest opportunity for a revival of interest in chamber processes lies in the Gaillard and Mills-Packard processes. The former has been very favorably received in Europe. So far, there have been only partial installations of Gaillard dispersers in two plants in

Gaillard-Parrish Sulphuric-Acid Plant
Recently Completed in London



the United States. Mills-Packard plants have already given a satisfactory account of themselves here. A logical combination of the most important features of the two has been attempted in London. This is a standard Gaillard-Parrish plant, with the exception that it has been equipped for external water-cooling of the chambers as in the Mills-Packard system. Experiments have not yet reached the point where the results can be published, although it is hoped that they will be available within a few months.

An interesting new method of burning pyrites in a manner similar to powdered coal has been developed by Horace Freeman and has been the subject of two papers presented before the

Canadian Institute of Mining and Metallurgy. The pyrites is pulverized in a ball mill and dried simultaneously with hot air. It is then blown into a furnace, where its rapid oxidation produces a gas containing 12 per cent SO₂. This gas is rapidly cooled in a waste-heat boiler where it generates more than 1 lb. of steam per pound of pyrites, which is more than enough to provide power for the operation. The cooling is so rapid that there is only about 0.1 per cent of SO₂ formed. An idea of the equipment set-up where the SO₂ is to be used in a paper plant may be gained from the accompanying drawing, which has been taken from a paper given by Mr. Freeman before the March, 1931, meeting of the Institute.



LIME WITNESSES A KILN BATTLE

◆ FOR MANY YEARS THE MANUFACTURING processes used in the lime industry were at a standstill. The kilns used were of a type that was actually obsolete 50 years ago. Even today most lime is burned in kilns that are wasteful in fuel and labor, high in maintenance, and low in output. In the last few years, however, there has been a change for the better and although the trend toward improved burning methods is somewhat slow, it nevertheless exists.

What the outcome of the search for better kilns will be, no one can safely predict. The search has led in three directions: toward the rotary kiln, the vertical gas-fired kiln, and the mixed feed kiln. The first has the advantage of a low labor requirement, but it is inefficient thermally. However, when powdered coal can be used as fuel and the waste heat can be utilized, the disadvantage of lower efficiency is not conclusive and it is probable that the rotary has an excellent chance of surviving.

There seems to be no question but that the small vertical shaft kiln of 10 to 15 tons daily capacity is doomed. Its direct descendant, however, an induced-draft vertical of great height and large volume, is an important competitor. It is generally fired with producer gas from automatic, centrally controlled producers, and has a capacity up to 80 tons per day. It is capable of producing the purest lime with a fuel ratio of over 5 tons of lime per ton of coal. Although its smaller ancestor could not compare with the rotary in labor, the gas-fired vertical requires even less attendance than the rotary.

Highest fuel efficiency is attained in the third type, the mixed-feed kiln. This is the form which has been used in many chemical plants and it has consequently been steadily improved. It yields the highest percentage of CO₂ in the flue gases, an important factor where the gases are to be used. There is practically no limit to the size which can be built, a capacity of 200 tons per day being entirely possible. Such kilns are susceptible to fully automatic charging and drawing. Production rates can be high, as forced draft as great as 15 in. of water may be utilized.

REFINEMENTS IN DESIGN FOR MECHANICAL SEPARATION

By ANTHONY ANABLE

*The Dorr Company
New York*

◆ IT WOULD BE TRITE TO remark that the unit operations embraced by the all-inclusive term "mechanical separation" play a large and often determining role in the operating cycles of most chemical engineering industries. These basic unit operations are today solving a myriad of industrial problems ranging from the separation of solids from solids according to size to the separations of liquids from solids by the use of gravitation, vacuum, pressure and centrifugal force. The operations with which the article is concerned are known to chemical engineers as classification, sedimentation, filtration, centrifuging, and screening. Differing, as they do, in principle and purpose, they are nevertheless closely interrelated in that they are all frequently to be found at different stages in the same process cycle and each one has been developed to a high degree of mechanical perfection.

The price of continued progress among the equipment manufacturers producing machines for these unit operations is continuous research and development, constructive improvement in design and materials of construction, and a steady broadening of the fields of usefulness to industry. While the manufacturer of chemical equipment does not bring out new models each year, like the manufacturer of automobiles, still a year seldom passes without one or more distinctive improvements, based upon technical analysis and provision and an anticipation of the future needs of industry. An audit of progress made in design shows that the practice of mechanical separation has been greatly enriched since the time of the last chemical exposition, in the spring of 1929.

CLASSIFICATION, BY COMMON usage, implies the wet separation of suspended solids one from the other in accordance with their hindered settling rates, which in turn are proportional to the sizes of the particles, assuming, of course, that all particles are of the same character and specific gravity.

Classifiers are widely used in the chemical industry in the preparation of finely divided pigments, such as lithopone, in washing of crystals free from solution, such as salt and electrolytic caustic, and in draining and sizing crystals, abrasives, and other water-suspended substances.

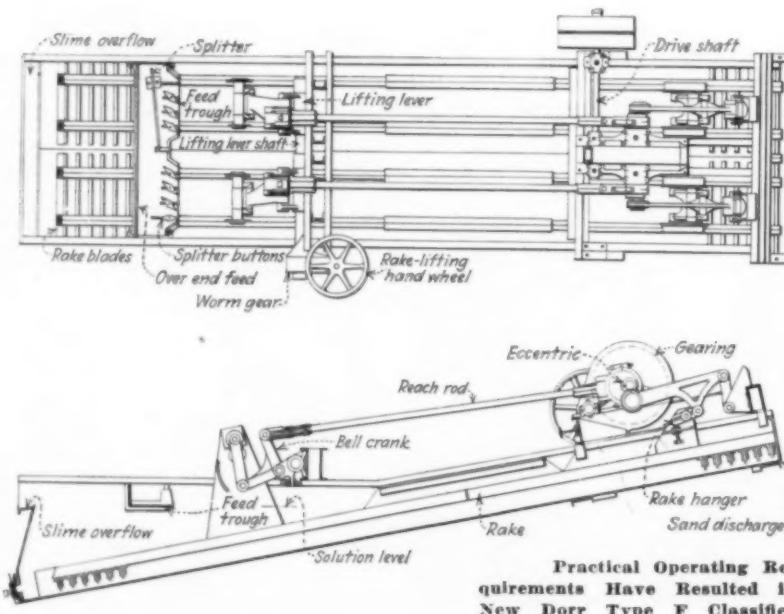
The Dorr Company has just introduced a distinctly new type of mechanical classifier which differs in design and construction from its predecessors. This new machine, the Type F Dorr classifier, employs an entirely new mechanical principle. It is shown in the accompanying drawing.

Smoothly running eccentrics, cranks, and linkages have replaced the cams and rollers used heretofore. The adoption of a simpler and more rugged design throughout has resulted in a reduction in parts amounting to 22½ per cent and a reduction in the regularly and infrequently lubricated parts of 33 and 50 per cent respectively. All working parts are constructed of cast steel; tank and structural members are of heavy welded construction; and all bearings subject to heavy duty are of the ball- or roller-

bearing type. Headroom has been materially reduced and this new unit may be operated at speeds 50 per cent in excess of that of the former model.

SEDIMENTATION IS THE TERM generally applied to the separation of the solids from the bulk of the solution in which they are suspended, by simple gravitational settlement. Continuous sedimentation apparatus provides for continuous introduction of the solid liquid mixture, continuous overflow of the clarified liquid, and continuous collection and removal of the settled solids from the bottom of the sedimentation tank. Continuous sedimentation or continuous thickening is used in a great variety of chemical operations where a precipitate is to be removed from its suspending solution or where the residues of acid digestion or leaching are to be separated from the valuable solution they have yielded. Continuous sedimentation finds its greatest usefulness, however, in connection with continuous counter-current decantation plants for the manufacture of such chemicals as caustic soda, phosphoric acids, aluminum sulphate, and the various barium chemicals.

A new type of thickener developed this year is known as the Dorr thickener, Type G; it was first devised to solve a particular problem in the



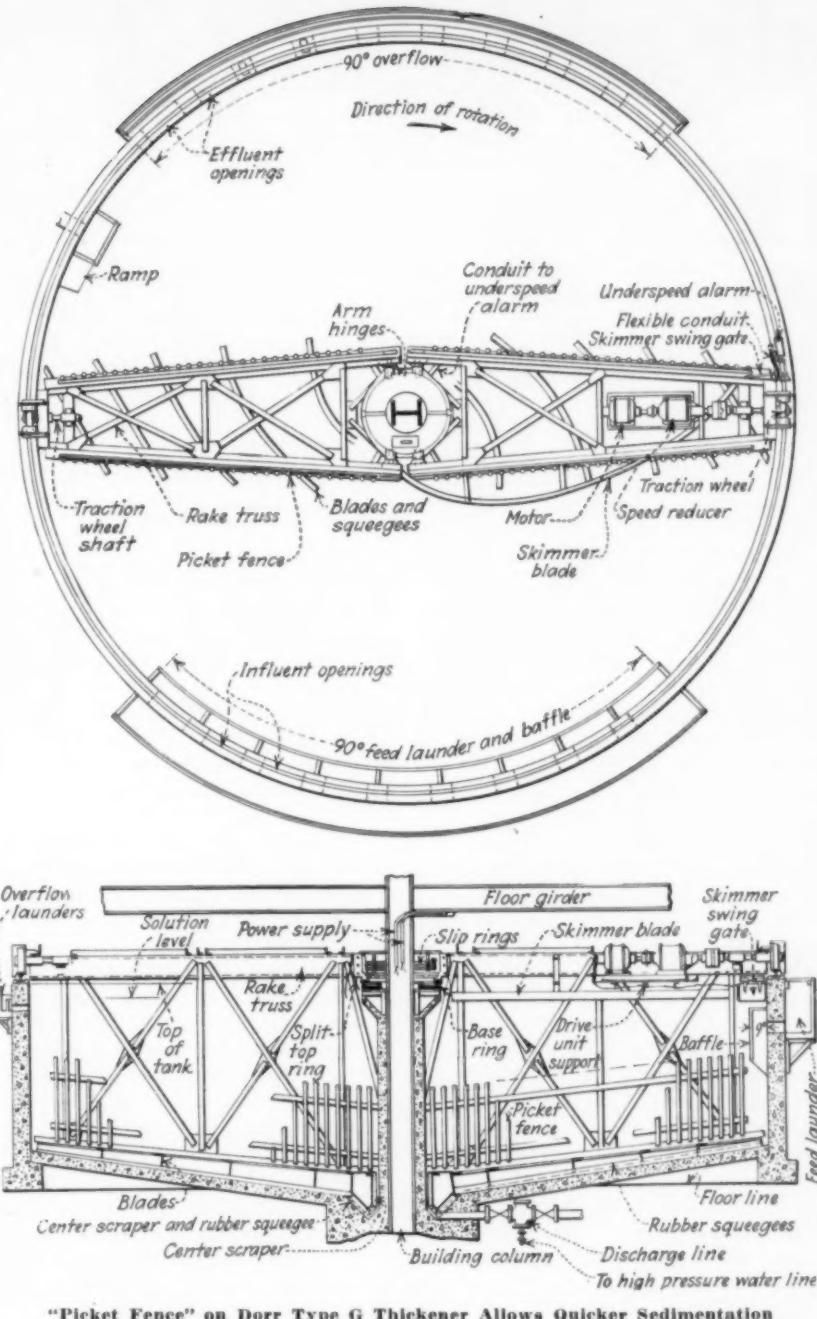
treatment of gluten at a corn products plant. Through certain modifications in the design of the raking mechanism of the Dorr traction thickener it has been found possible to induce such a gentle stirring action that the solids settle to a greater density than otherwise. The new principles employed are basic, hence the same extra thickening is secured with a variety of materials other than gluten, such as clay, sewage, sludge and various other precipitates of a flocculent character. The new construction is evident from the adjacent drawing.

The design features of this new Dorr thickener are deserving of comment because of the new principles involved. The mechanism is similar to that of a standard Dorr traction thickener in basic features, but differs specifically in that vertical stirring arms are attached to the driving truss and the extension arms. These stirring arms are located on 6-in. centers, have a cross-sectional width of $1\frac{1}{2}$ in., and are just long enough to extend from the tank bottom to the top of the zone containing pulp in the compression stage. The general appearance is that of a picket fence.

FILTRATION IS THE PRACTICE of removing the bulk of the solution from a solid-liquid mixture by causing the solution to pass through a medium upon which the solids are retained in the form of a cake, this separation being effected through the application either of pressure on the cake-forming side of the medium or of vacuum on the side from which the solution is withdrawn. Plate and frame presses and the variant forms of continuous vacuum filters are important working tools of the chemical engineer. Few, indeed, are the chemical processes having solid-liquid phases which do not employ filtration at some stage in their cycle. There have been many improvements in the design of filtration apparatus, especially in connection with continuous vacuum filters. Since space does not permit a complete survey of design changes in the entire field, this discussion will deal only with improvements in the design of filters of the continuous vacuum type.

The Oliver-United Filters, Inc. has brought out a new filter, known as the Top Feed Oliver Filter. It is adapted especially to the handling of coarse materials, crystalline substances, and the like containing only a very small proportion of fine material. It gives high capacities on such materials and a very low moisture content of cake. In certain cases the cake may be discharged practically bone dry by preheating the air drawn through the cake during the drying cycle.

As the name implies, the distinguishing feature of this filter is the delivery of the feed upon the top of the drum and upon the ascending quadrant. Construction detail is shown on the next page. Internally the drum is similar in con-



"Picket Fence" on Dorr Type G Thickener Allows Quicker Sedimentation

struction to that of a standard Oliver, except that larger drainage pipes and conduits are used. Externally the drum differs by reason of a flange on either end for the retention of the charge, since, of course, no filter tank is used. In some installations the drum is entirely inclosed and the drum proportions are somewhat different, as the face is shorter in proportion to the diameter than in the conventional type of drum filter.

The charge in this unit may be retained around 80 per cent or more of the drum's circumference before discharge, thus providing an exceptionally long drying period. The released cake is discharged into a hopper or chute which occupies the position of the filter tank on the regular Oliver.

The Dorr Company has introduced a new type of salt filter, particularly

adapted to the use of metallic filter media and the use of preheated air for drying. It is constructed generally of cast iron and special metals and has especially large passages for handling large volumes of air. The panels into which its circumference is divided are made up as separate detachable units, machine fitted and clamped together to form the drum. They may be replaced quickly by loosening clamps, removing an individual panel, and inserting a spare with a minimum of interruption.

The stationary end plate seal is provided with an inspection door. The passage through the center of the port valve serves as the inlet for the pre-heated air. The cake is discharged in an inclined chute passing through the end plate and feed is introduced in a pipe, also through the end plate.

In the case of free filtering materials,

permitting high speeds of filter operation and the handling of large tonnages on comparatively small drums, the face width of the standard Dorco filter has been reduced in proportion to the diameter. The new short-face Dorco filter, equipped with a chute discharge instead of a conveyor belt, is being used to advantage where drums of conventional proportions give trouble in obtaining proper distribution of extremely coarse, heterogeneous material in a shallow bath of pulp.

A modified Oliver known as the Oliver Cachaza filter, for handling cachaza, the settling from defecated cane juice, differs little in outward appearance from the standard, but the construction details are quite different. The tank is shallower, giving a very low drum submergence, and the drum is divided into very shallow vacuum chambers. Brass screen is used as a filter medium, which, it is said, makes it unnecessary to recover oftener than every three to five crops.

Cake is discharged by a rubber belt discharger held against the surface of the filter by counterweights. This arrangement permits the complete discharge of even the thinnest cake. The automatic filter valve has three ports, or outlets, permitting the filtrate obtained during cake formation, and frequently cloudy, to be recycled and kept separate from the other two filtrates, which are clear.

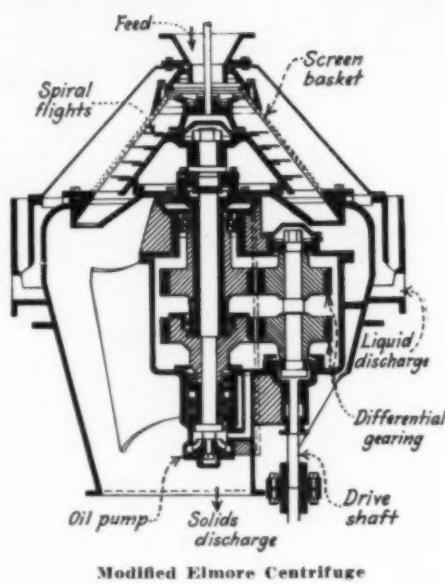
It is reported that the cast-lead Oliver filter has been perfected and operated successfully, handling concentrated phosphoric acid direct from the digestion tanks. Phosphoric acid at 26 deg. Bé. and 106 deg. F. has been handled and the gypsum cake has been delivered with only about 0.2 per cent soluble P_2O_5 (dry basis). The Dorco rubber-covered filter has proved satisfactory in handling phosphoric acid. An improved type of filter medium, "Doracid," made

from nitrated cotton, is used in this case.

Oliver filters in the paper field may now be equipped with vacuum discharges and rubber-covered discharge rolls, permitting a clean removal of the sheet without injury to the filter medium. Improved division sheets on the board-forming machine make possible the formation of a continuous board without cross-marking, while the use of press rolls on brown stock washers improves the density and washing results.

CENTRIFUGING. THE APPLICATION of centrifugal force to the removal of solution from granular or semi-granular substances, is a mechanical separation operation which finds wide application in the chemical industry. Salt, crystals, and in certain cases chemical precipitates are readily dewatered and washed in the various types of centrifugal machines.

The Elmore centrifuge has been materially improved during the last year or so and certain refinements in design are shown in the drawing. The continuous centrifuge, it will be remembered, has two rotating elements, the outside conical screen frame and the inside solid cone carrying the spiral hindrance flights which hold the pulp in position and facilitate the discharge of the dewatered solids. Both rotating elements revolve in the same direction but at different speeds, the screen element revolving slightly more rapidly. Material enters at the top, is thrown radially outward, by the cone, upon the screen surface, whereupon liquid instantly begins to pass through the screen and thence to storage via a circumferential launder surrounding the top of the main outer casing. The spiral hindrance flights, by reason of the speed differential between the screen and the cone, force the material downward across the screen to the point of discharge, at the lower rim.



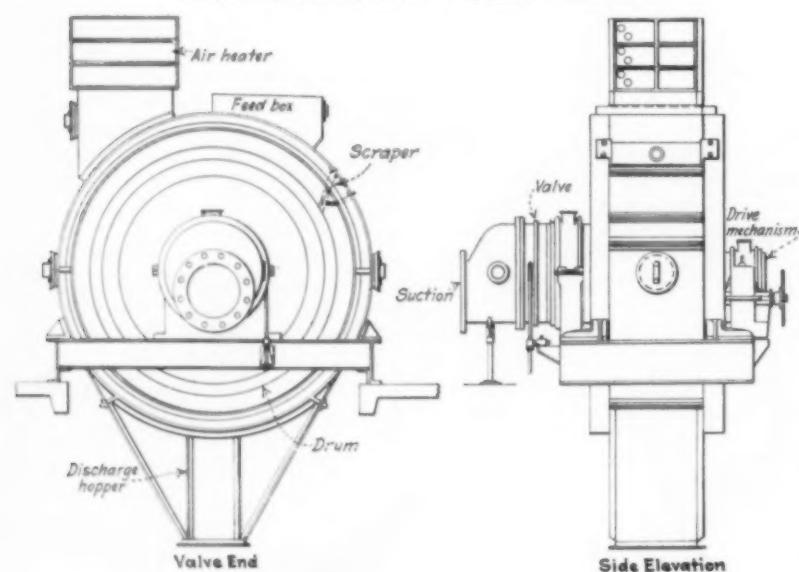
The new Elmore centrifuge has a truncated conical screen with an angle of 50-52 deg. as against the 72-deg. angle used formerly. At 50-52 deg. it was found that nearly all material fed to the machine while running would slide down the sides of the basket and discharge readily through the base of the machine. This led to a rearrangement of the flights attached to the cone. In the new design these have become spiral hindrance flights rather than scraping flights, actually dragging the material from the screen surface.

The redesign of the screen basket has greatly reduced the wear on the differential gears, as the only service imposed is that of progressing 10 to 15 lb. of material through the machine at one time and overcoming of the inertia during starting. Power consumption has accordingly been reduced 50 per cent.

Other improvements include the elimination of bevel gears, the use of a direct motor drive and hanging the machine at a point near its middle rather than mounting it rigidly upon the floor. A centrifugal oil pump is now used to provide positive lubrication for the differential gears and other wearing parts. An improved method for adjusting the spiral hindrance flights has been adopted, so that wear may be compensated easily by changing the location of the spiral with respect to the screen.

A significant advance in screening media has been made by the Elmore engineers. It consists of a series of rings, $\frac{1}{2}$ - $\frac{1}{2}$ in. thick, lying loosely on the basket, one above the other and held by a clamping ring at the bottom of the basket. The face of each of these superimposed rings is milled to form radial slots $1\frac{1}{2}$ in. long on $\frac{1}{4}$ in. centers. The openings formed by these milled recesses may be of any size from $\frac{1}{4}$ in. up to as coarse as may be required for the material handled. The slots formed in this manner provide the equivalent of the perforations in a

Oliver Top Feed Filter For Coarser Material



punched screening plate, but the thickness of the rings is such that many months of wear can be secured even when handling abrasive material.

The De Laval Separator Company reports the commercial development of the De Laval-Funk process for maintenance of the lubricating qualities of turbine oil and control of the acidity value or neutralization number of the oil. The conventional type of oil purification system attempts to combat the injurious effects of the sludge formed in lubricating systems by removing it after formation by centrifugation or other methods. Not so, however, the De Laval-Funk process, the distinguishing feature of which is the actual prevention of the formation of the sludge itself.

The first step in the deterioration of oil is the formation of oxyhydrocarbons, which attack metals only slightly but lead to the formation of metallic soaps, which, in turn, accelerate sludging and the formation of emulsions. Some of these oxyhydrocarbons, when first formed, are about ten times more soluble in water than in oil; on this fact this anti-sludging process is based.

A stream of oil is continuously drawn from the bottom of the turbine reservoir into an especially constructed processing tank where it is brought into contact with condensate under conditions favorable to the formation of sludge and absorption by the condensate of oxyhydrocarbons. The sludges resulting from the combination of oxyhydrocarbons and water are formed in the processing. It is understood that tests recently on two identical turbines, one equipped with this oil-treating process and one not, showed for the process-equipped turbine, reductions of 87 per cent in sludge formation, 84 in the development of acidity, and 54 in make-up oil requirements.

The W. S. Tyler Company, Cleveland, Ohio, has recently introduced a distinctly

new type of vibrating screen which is known as the Type 38 Hummer, shown in the illustration below on this page. It uses a multiplicity of superimposed screening surfaces with a single unit and an improved method for tensioning the wire cloth and attaching the vibrators. According to actual tests this improved tensioning of the media and attachment of the vibrator has made it possible to obtain much higher screening efficiencies than with earlier types. This machine has been built with as

many as four superimposed screening surfaces in one machine and it is being used in a number of industries for separating materials into certain definite divisions and for proportioning into products of a given density or porosity of aggregate. By the use of special steels the life of wire cloth has in many instances been increased to two to three times that of the regular steel wire. The cost of this new screening media is only slightly greater than that of the conventional type of cloth.

EVAPORATOR DESIGN SHOWS MODERN TREND

By W. L. BADGER

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Ann Arbor, Mich.

EDITOR'S NOTE: In Chem. & Met. for Sept. 10, 1923, Professor Badger contributed a general discussion of evaporator types. In the Modernization number for September, 1928, he gave a discussion of some recent improvements in evaporators. The present article should be considered a continuation of this series.

◆ PRIOR TO 1923 THE HORIZONTAL-TUBE evaporator was built by different makers with a rectangular body, or with the body in the shape of a vertical cylinder, or of a horizontal cylinder. All three types have been used almost since the beginning of multiple-effect evaporation. The cylindrical bodies usually were built of ring castings; the rectangular bodies of flanged flat plates. In 1928 it was noted that the tendency was definitely away from the flat-plate construction and that the vertical cylindrical shell was becoming more important. In the past few years this tendency has been emphasized so that now relatively few rectangular body horizontal-tube evaporators are built. Certain industries, such as the beet sugar industry and the malt syrup industry, are familiar with this design and in some cases still demand it. The type with the vertical cylindrical body is so generally accepted, however, that it may be considered the standard. Horizontal-tube evaporators of the third type, with the body in the form of a horizontal cylinder, are rarely built.

The field of the horizontal-tube evaporator is still very much the same. It is indicated for boiling clear, non-viscous, non-scaling solutions; or for those cases where tube renewals are

frequent and hence cost of tube removal must be kept low. The horizontal-tube evaporator is best suited for construction in certain special metals such as lead or aluminum.

One type of horizontal-tube evaporator that was classed with film-type evaporators in the 1923 classification will be discussed here. The general subject of film evaporators will be taken up later. The Yaryan evaporator has had a rather checkered history, but has never seemed to be properly oriented with respect to the other types. It has only one important advantage: it handles foamy liquids quite satisfactorily. This can now be done equally well in another type. Practically the only important place where Yaryan evaporators are now used is in the distillation of gasoline and pine oil in the recovery of naval stores by extracting waste wood.

Vertical-tube evaporators may be roughly separated into two general classes: first, the short-tube type; and second, the long-tube high-velocity type. In the classification of evaporators given by the writer in 1923 a separate group of types was given the general name "film" evaporators. One rarely hears this term at present; and it is now generally recognized that there is no real difference between the so-called "submerged tube" evaporators and the so-called "film" evaporators. Any vertical-tube evaporator may be operated with high liquor levels, so that it may be called a submerged-tube machine; or it may be operated with low liquor levels, in which case its performance passes over more or less completely to the so-called film types. This distinction is, of course, more marked with the long-tube construction.

The submerged-tube type of vertical-tube evaporator probably is the best

Superimposed Type 38 Hummer Screen

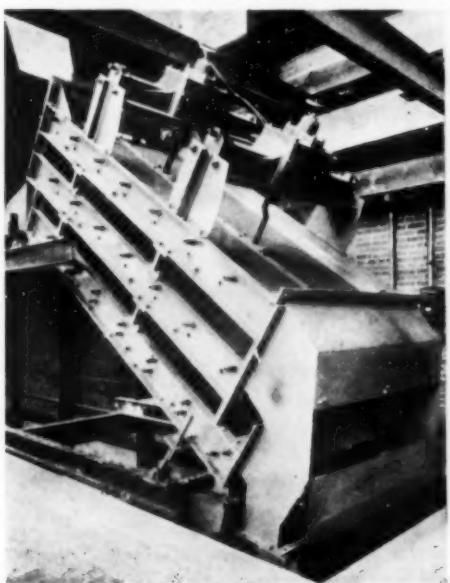




Fig. 1—Triple Effect Basket Type of Salt Evaporator From the Operating Floor

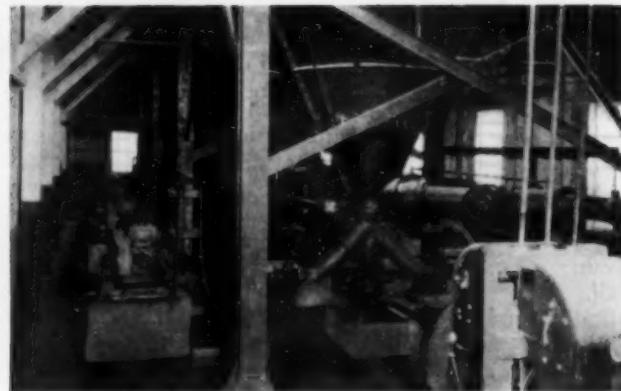


Fig. 2—Lower Part of Evaporator of Fig. 1 Showing Salt Pumps and Propeller Drives

known and most widely used of all evaporators. It was so thoroughly worked out in the early days of the industry that no important changes have been made in any detail for many years. In 1923 two types were described, the ordinary standard type with a central down-take, and the basket type with an annular down-take. Some rather large basket-type evaporators were described in 1928, together with a continuous system of salt removal. Figs. 1 and 2 show the evaporator there described, and Fig. 3 shows one of the heating elements. This evaporator has proved in operation to be decidedly superior to the standard type evaporators of the same general design, in which case the propellor must be located in the central down-take. It is questionable, however, whether this type is practical in sizes over 12 to 13 ft. in diameter. Very large units, such as are now often demanded, running from 18 to 20 ft. and even larger in diameter, probably will continue to be built with a central down-take for structural reasons. Definite attempts are being made to find a more positive method of circulation than has been used in the past, but no completely satisfactory answer to this problem has been found.

The second group of vertical-tube machines—namely, the long-tube high-velocity type—has seen marked development in the last few years. In the 1923 analysis only the Kestner was described. The Kestner evaporator as such has never been successful in the United States, in spite of its wide adoption in Europe.

One of the difficulties with the Kestner evaporator was the fact that liquid passed through the evaporator only once and therefore the feed had to be controlled very carefully or the tubes would go dry. The operator usually preferred to err on the other side, and tended to put the liquid through with too little concentration. The obvious cure for this situation was to supply a return tube from the vapor head back to the feed chamber of the same effect. This was done some time ago, but was not mentioned in the 1928 analysis. In the last three or four years there has been

considerable activity on the part of most builders of evaporators in perfecting and marketing various modifications of this design. The Buffalo Foundry & Machine Company has installed a number of evaporators of this type for use on black liquor, malt syrup, and condensed milk. The tubes vary from 7 to 10 ft. in length up to 20 ft. in length. The Zaremba Company and the E. B. Badger Company also have built such evaporators. These are operated with relatively low liquor levels, so that velocity in the tubes is high and the heat transfer coefficients are correspondingly large. The general interest in this type of evaporator is really the only important development in the last four years. The Zaremba Company has brought out a long-tube falling-film evaporator that properly belongs in this class.

The other important development in the line of long-tube high-velocity evaporators (the forced circulation evaporator of the Swenson Evaporator Company) was well under way at the time of the 1928 review. It was not mentioned in the 1923 article, because at that time it had not even been thought of. A single effect was shown in the 1928 article and some of the advantages of this type were discussed. At present it is in use in almost every caustic-soda plant in the United States. It is also

used for the evaporation of paper-pulp liquors, glycerine and soap lyes, common salt, fermentation slop, and petroleum distillate. The distillation of lubricating oils with diphenyl heat, as carried out by the Indian Refining Company, is done in equipment built under the forced-circulation patents.

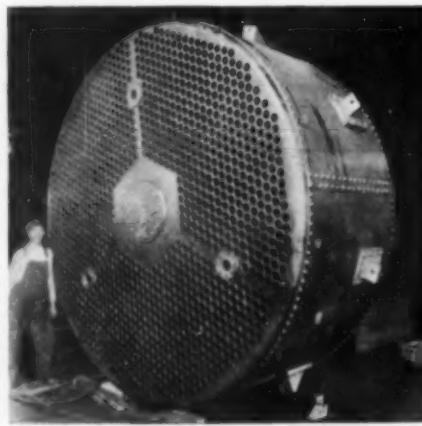
The advantages of the forced circulation evaporator were covered in the 1928 article and do not need to be repeated here. It is sufficient to say that in the 60 to 70 effects now in operation, all these advantages have been fully brought out in practice. Fig. 4 shows a typical layout of a double-effect forced-circulation evaporator with salt separators on each effect. Fig. 5 shows a heating element for a forced-circulation evaporator for electrolytic caustic. The tube sheets and tubes are of nickel, and the shell is covered with nickel.

In the 1923 analysis the Lillie evaporator was classed among the film-type evaporators. This evaporator has practically disappeared from the picture. The inclined-tube evaporator was also mentioned in the 1923 analysis and its use in evaporating milk was mentioned in the 1928 article. At present it is felt that the long-tube high-velocity designs, of either the natural circulation or the forced-circulation types, give as high or higher heat-transfer coefficients, equal safety for sensitive materials such as milk, occupy less floor space, and are more easily cleaned.

No evaporator that has appeared during the past four years and received any acceptance in practice shows any marked deviation from the various standard types outlined above.

Since 1928 the pressure evaporator has made no more headway in the United States than was apparent in the previous article. The removal of salt by continuous pumping has met with greater and greater favor, and is now used not only on large salt evaporators but on most operations, large or small, in which any crystalline material is to be removed. In the case of evaporators for electrolytic caustic soda solutions where salt must be removed from several effects, each containing liquor of a different composition, much more com-

Fig. 3—Heating Element for Evaporator Shown Above



plicated flow sheets are necessary than the simple diagrams shown in 1928. For common salt evaporators, or for any other case where the composition of the liquor is the same in all effects, the flow sheet shown in 1928 is standard. The only marked change in recent years has been the almost complete substitution of rotary continuous vacuum filters for centrifugals, and in the case of very fine material, continuous centrifugals.

During the period between the 1928 article and the present, a business boom has been followed by a depression. During the boom there was no interest in adding more bodies to existing effects, because this would not increase capacity. The depression has been such that many manufacturers have not been willing to spend money for equipment, even though it would result in decreased operating costs. Nevertheless, the writer is firmly convinced that at present many concerns operating multiple-effect evaporators should give consideration to the question of whether or not, by increasing the number of effects, steam consumption and, therefore, operating costs might be lowered. If the plant is equipped with old-style submerged-tube evaporators, which necessarily require a considerable temperature drop for satisfactory operation, it is sometimes possible to increase the initial steam pressure sufficiently to provide for the addition of another effect. If this cannot be done, an addition of the long-tube high-velocity type can often be made; and because of its ability to work on very small temperature drops such an additional body does not greatly disturb the operation of the other effects or require an increase in steam pressure. This corresponds to the development that took place in the European beet sugar industry between 1890 and 1900, when practically every old double- or triple-effect submerged-tube evaporator was provided with one or more Kestner pre-evaporators to decrease operating costs.

Theoretically, the results suggested above could also be obtained by the use of a vapor recompression system. In 1923 the writer discussed vapor recompression at length and came to the conclusion that there are relatively few cases in this country in which it could ever be considered practical. Within the last two or three years one case has been found where vapor recompression is apparently having decidedly useful results.

The Zaremba Company has supplied a number of single-effect evaporators provided with steam-jet vapor compressors for the evaporation of fruit juices and similar materials. These materials are all characterized by their tendency to suffer a change in flavor unless they are boiled at the lowest temperature possible. This effectively eliminates any possibility of multiple-effect operation. If, however, an evaporator is built with a reasonably high

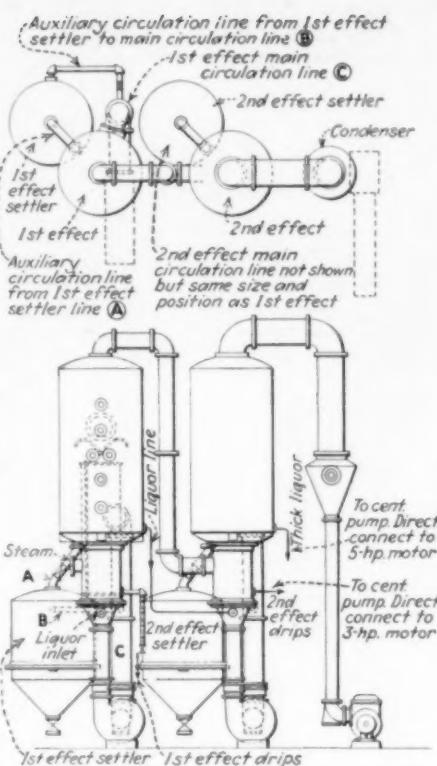


Fig. 4—Double-Effect Forced-Circulation Evaporator With Salt Separators on Each Effect

heat-transfer coefficient so that it can operate economically on small temperature drops, the application of vapor recompression is technically feasible, gives multiple effect economy (thereby reducing first cost of equipment), and maintains the required characteristics of the liquor. The writer is still of the opinion that if the necessity of boiling the liquid at the lowest possible temperature were eliminated, the same ends usually could be accomplished by ordinary multiple-effect operation.

The last four years has shown a remarkable lack of any literature dealing with the theory of evaporators. Othmer,¹ Colburn and Haugen,² and Monrad³ have all published work on steam film coefficients. This, of course, is impor-

tant and necessary; but without similar information regarding the liquid film resistance, rational analysis of evaporator performance is still impossible. Only one article has appeared in the last four years on over-all coefficients of heat transfer in evaporators: namely, by Linden and Montillon.⁴ Other than that, the only published articles on evaporators have been discussions of patents, of special applications in special plants, or other items of no importance so far as theory is concerned.

One extremely important contribution has just appeared. Hausbrand's classic book, "Verdampfen, Kondensieren, und Kühlen," probably is known to most engineers in this country from the English translation, which, unfortunately, was never carried beyond the second German edition of 1902. The seventh German edition of 1918 contained at least 50 per cent more material; but, unfortunately, was unsuccessful in correlating the more modern work on heat transfer with the older material of the previous editions. Hausbrand's death in 1922 apparently put an end to this series of editions, now largely important because of the honorable place they held in the development of evaporator design. However, the publishers of Hausbrand arranged with M. Hirsch to bring Hausbrand's book up to date, and the new Hausbrand-Hirsch appeared within the last few months. The book is entirely rewritten; nothing is left of the old Hausbrand book. Hirsch has contributed an entirely new method for the design of multiple-effect evaporators—a graphical method based on a total heat-temperature diagram. Unfortunately, the terminology is very complicated and it probably will be some time before the book is translated into English, so that its value to engineers in this country will be limited.

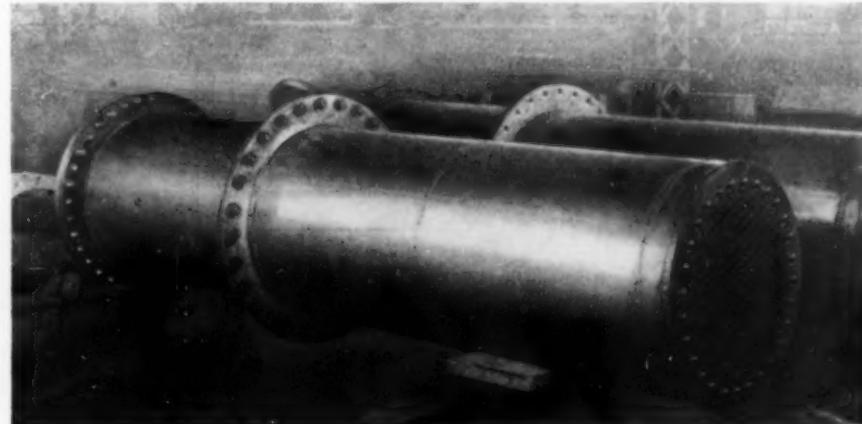
¹Ind. Eng. Chem. Vol. 21, pages 576-83 (1929).

²Ind. Eng. Chem., Vol. 22, pages 522-39 (1930).

³Trans. Am. Inst. Chem. Eng. Vol. 24, pages 84-119 (1930).

⁴Trans. Am. Inst. Chem. Eng., Vol. 24, pages 120-41 (1930).

Fig. 5—Heating Elements for Forced-Circulation Evaporator. The Tubes and Tube Sheets Are of Nickel and the Shell Is Nickel Covered



DISTILLATION ADVANCES IN COLUMN DESIGN

By D. B. KEYES

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◆ DISTILLATION HAS COME TO mean not merely the evaporation of a liquid at the boiling point but also the fractionation of a liquid mixture into its separate components or compounds. The art of fractionation was highly developed in the alcohol industry long ago, but recently it has been advanced by engineers working in the motor fuel industry.

The design of fractionating columns is part of a larger subject¹. The fractionation of a liquid mixture requires intimate contact between a gas and a liquid. The ordinary fractionating column consists of a heating device at the bottom of the column to produce a vapor, a feed line entering the column somewhere between the bottom and the top, and a reflux condenser at the top of the column to supply the liquid which cascades from plate to plate or section to section. In brief, the fractionating column consists of a counter-current scrubber, a liquid going down and a gas going up.

Fractionation in the past involved the use of filled or packed columns and plate columns, and that is all. No attempt was made to utilize spray columns, fixed or moving, for the purpose of fractionation. On the other hand, the operation of scrubbing a gas with a liquid, the evaporation of a concentrated solution, and the chemical reaction between a gas and a liquid have all been tried in equipment involving the use of sprays and other novel features.

The filled column is still important, of course, for the fractionation of very corrosive liquids, because it is the one column that can be easily constructed out of stoneware and similar acid-resisting material. No great advances have been made in this type of column in the last few years.

The perforated plate column, although simple in its construction, as indicated by Fig. 1, strange to say, has not increased its popularity; in fact, it has decreased in general use. The beer still of the alcohol industry is of this type and probably will remain so for some time. Perhaps the outstanding disadvantage is the fact that the liquid layer is supported by the gas pressure. The fluctuating gas pressure is liable to

cause trouble, because once the gas pressure drops below a certain amount, depending on the construction of the column, the liquid will promptly drain through the perforations from plate to plate. Its simplicity of construction, on the other hand, is to be kept in mind. Ofttimes, besides fractionation, one desires a certain amount of chemical reaction to take place upon each plate. In these cases it usually is necessary to control the temperature by the utilization of heating or cooling coils. The perforated plate column can be equipped with these coils much more readily than the bubble-cap column.

Bubble-cap columns have become recognized as the most efficient of all ordinary

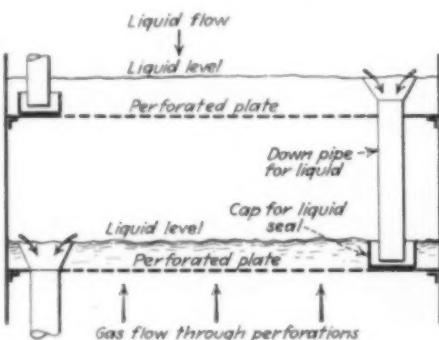


Fig. 1—Perforated Plate Column

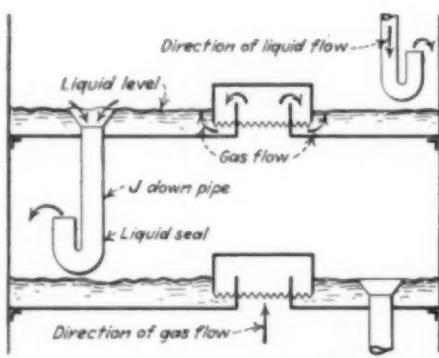


Fig. 2—Bubble Cap Plate Column

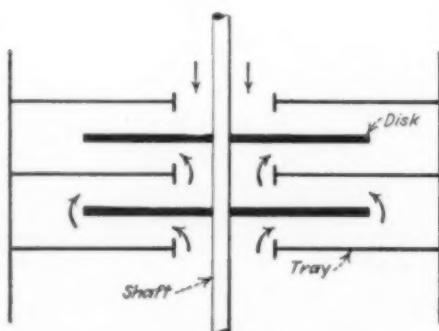


Fig. 3—Whirling Spray Column

nary types of fractionating columns. Their popularity in oil refining has increased enormously in the last few years. Unlike the perforated plate column, they have a permanent liquid layer on each plate, as indicated in Fig. 2. The gas pressure may vary considerably without materially decreasing the efficiency of the column. Of course, this type of column has a definite back pressure and cannot be used effectively for vacuum distillations; nor does it lend itself readily to the utilization of acid-resisting material. Plates of glass construction, however, have been developed in the last few years and are now sold in fairly large sizes as standard equipment. This development is described on the opposite page.

Considerable work has been done by equipment concerns and by engineers in the motor-fuel industry to increase the length of path of the liquid on the plate. As in all other types of columns, the essential from design standpoint is high plate efficiency; in other words, to bring about equilibrium between the vapor and liquid. Designers have attempted to accomplish this by making the bubbles of gas very small. Recently, however, it has been appreciated by several of our chemical engineers that perhaps the real contact between the gas and the liquid was obtained not in the liquid layer but just above, where the boiling or frothing takes place. Here we have liquid in the form of small bubbles inclosing the gas. In fact, modern designers require that a certain quantity of this so-called froth should be present on every plate.

In order to bring about these conditions it is sometimes necessary to create considerable spray. If this spray is carried up to the plate above, it naturally disturbs the equilibrium and reduces the efficiency of the column. In the last few years this matter has been considered by various chemical engineers and some excellent designs consisting of baffling arrangements have been created in petroleum refineries.

IT HAS BEEN FOUND THAT the time of contact between a gas and a liquid necessary to bring about equilibrium conditions in the common systems is extremely short. With this in mind, the importance of equipment which distributes the liquid in fine droplets through the gas can be appreciated. Even though the gas passes through a fog of liquid at a relatively high velocity, the equilibrium conditions usually are obtained. In practice, a simple revolving disk, as in Fig. 3, will send a fine spray to the walls of a column and actually function in the same manner as a fixed plate of common design. In a distilling operation the liquid cascades from plate to plate, falling near the center of the revolving disk, and is then thrown to the sides while the gas passes up through the spray and over a pool of liquid in doughnut-shaped trays. These trays are to collect the spray in order that it may be again sent to the disk below.

1. See "Equipment for Gas-Liquid Reactions" by D. B. Keyes, Circular No. 19, Engineering Experiment Station, University of Illinois, October, 1929.

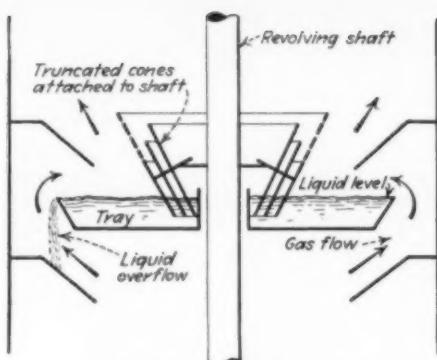


Fig. 4—Whirling Cone Spray Column

It has been found by petroleum refiners that such a column will operate very effectively in the vacuum distillation of lubricating oils. The back pressure, of course, is very small and apparently the efficiency of each section is relatively high as compared to the ordinary plate. It should be noticed, furthermore, that the capacity of such a column is considerably greater. In other words, the height of this column is less than the equivalent column of common design.

It may also be noticed that this simple whirling spray column can be made of an acid-resisting material or at least surfaced with lead, without materially increasing the cost of maintenance. It also can be seen that this type of column can contain cooling or heating coils within the trays without disturbing the operation or interfering with the general efficiency.

Another type of column which probably has never been used for fractional distillation, but which undoubtedly can be adapted for that purpose with the distinct possibility of very interesting results, would be the revolving cone type of column shown in Fig. 4. This type of column has been used for scrubbing gases with considerable success, but as the operation of gas scrubbing is so similar to that of fractional distillation, the type is worth investigation for this latter purpose.

The truncated cones attached to the revolving shaft have a tendency to agitate the liquid in the doughnut-shaped pan within which they dip. The result is that the liquid climbs the side of the cone, goes over the edge and through a screen, with the result that it is broken up in what might be described as a rain. This is collected on a baffle and runs back onto the tray. Each tray has an overflow which connects with the tray below. The gases meanwhile go across the liquid surface above the tray and then through the rather dense spray and from there to the tray above. It operates at a very little back pressure and probably will give more time of contact than the one previously described.

THE REASON WHY WHIRLING spray columns have been tried in place of fixed spray columns in fractionation is that the former do not require a

special pump for each section in order to produce the spray, the centrifugal motion acting the part of the pump. However, at present we have some excellent spray nozzles. Where it is the question of gas scrubbing it has been found that these spray nozzles produce a cone of spray so uniform in physical composition that the contact between the liquid and the gas passing through this cone is most effective. It has been found, for example, in the experimental work involved in a certain gas-scrubbing problem that one of these sprays was equivalent to a packed column occupying a space of about five or six times the space occupied by the spray.

It is easily conceived that at some future date we may be able to construct fractionating columns consisting of sections in which a fixed spray is the means of bringing about the equilibrium between the gas and the liquid. As stated before, this will depend, however, on the design of effective small pumps which will be able to operate with hot liquids and at relatively high pressures.

DEVELOPING GLASS PROCESS EQUIPMENT

By A. E. MARSHALL
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New York

◆ CHEMICAL INDUSTRY ALways has had an interest in glass piping because of its mechanical and constitutional resistance to corrosion. As one of the first industrial forms of Pyrex chemically resistant glass made by Corning Glass Works, piping was produced in two forms: with bell and spigot joints, duplicating stoneware, and in straight sections with rubber-hose connection. Neither form was entirely adequate, because in one case pressure resistance was limited by the cement, and in the other, the rubber was only specifically resistant. Nevertheless, many successful installations of cemented socket pipe are in use, and the glass-rubber joint piping has also been widely adopted, one factory alone using over ten miles of it.

Meanwhile, a new joint was evolved incorporating straight sections of pipe and separate flange sections, which were welded together. Flanged members were clamped together with split metal flanges and a rubber gasket, to equalize the strain. In the course of development, this design has proved very desirable in many permanent operations, especially where high purity is required, as in a food plant. A simpler and more rugged form, for more frequent changes, was then sought. It was desired to produce rugged joints, easy to assemble and resistant to at least 50 lb. per square inch.

A year's experiment developed a new form of joint made by shaping pipes and tubes of constant bore, with flaring ends

of increased external diameter, the wall thickness increasing in proportion. Metal clamps, either solid or in two parts, with an interior section corresponding to the glass, serve to join two successive ends. These joints may be tightened by bringing together the flanges that constitute the clamp. While this development is only emerging from trial to the point of actual use, the experimental experience fortifies the belief in its widespread adoption in the future.

For several years, the Corning Glass Works has made perforated and bonnet plates for still columns and reaction towers, but only within the last six months has a serious attempt been made to produce an all-glass column. Tower walls are not particularly exposed to reagents, but metal often introduces undesirable impurities and does not allow a view of the reaction's progress. The glass column sections worked out are similar to the latest piping. Heavy glass rings are cast on the outside ends of Pyrex cylinder and after the ends have been ground plane and parallel, a perforated plate with ground edges is introduced between the column sections, joined by an external metal clamp.

The first all-glass column was made in October, 1930, and because it greatly improved a heretofore difficult reaction cycle, the user of this first 13-in. column has ordered a series of towers 24 in. in diameter. The great advantages of an all-glass column are visibility of reaction, its corrosion resistance, and, because of the constant size of plate orifices after long operation, its long-continued efficiency. An interesting fact observed through these columns was the unsuspected loss of capacity through surges. The ability to study distribution of the liquid on the plates and the gas through the liquid will now permit more rational advances in fractionation column design.

Glass tubular heat exchangers are another variant of the use of Pyrex piping as a corrosion-resistant material. This application has long been conceded as desirable, but heat transfer seemed to be a discouraging limitation. However, careful laboratory studies showed that since heat-transfer efficiency is a function of the surface condition, surface perfection and surface wear were important factors. In the case of metals, contact with corrosive liquids gave decreasing heat-transfer values, while glass maintained its original rate. It was also found that while the initial heat-transfer rate of certain metals is higher than glass, the values tend to become equal after a few months, and subsequently the rating of the glass may even slightly exceed the metal.

As a result of these studies on heat-transfer rates, glass-tube heat exchangers with new types of tube sheets and new methods of packing have been developed. They are coming into general use in the chemical industries and are being employed experimentally in gas plants for cooling ammonia liquors.

GRINDING IMPROVED BY MILLS OF NEW DESIGN

By LINCOLN T. WORK

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◆ IN ANY CONSIDERATION OF crushing and grinding, the dual features of economics and of ultimate character of the product stand out conspicuously. The present important features of an economic nature are the power and maintenance considerations, direct labor normally being low. New tools of measurement have been made available for evaluating the fineness of ground products. With these tools the value of sub-sieve fineness may be defined and new milling requirements may be set. The dual features of cost and kind of product have become embodied directly in the construction and operation of the mills themselves, of the separators which operate the mills in closed circuit grinding, and of accessory equipment. It is primarily with respect to features of design that attention will be directed in this article.

There are indications that the actual energy needed to produce grinding is much less than 5 per cent of the actual energy consumed by the mill. How to apply the grinding forces in a manner that will reduce this great excess of energy has led to a diversity of mill types as follows: direct-pressure, roller, tube, beater, and revolving plate mills. The applicability of these types is in a large measure dependent on the manner in which the material will grind. Recently there has been an effort to evaluate ease of grinding quantitatively. If this is done, it should be possible to correlate grindability with mill types and to estimate the power consumption for any raw material.

The selection of certain types of mills in preference to others has been so frequently based on the maintenance factor that mill construction has definitely been aimed at lower maintenance. In those mills where high speed and limited wearing surface are necessary features of the design, manufacturers have made marked reduction in maintenance by the choice of material to make the parts more wear-resistant. Further, they have modified the design to make worn parts readily accessible for easy removal and replacement. As another phase of this problem, grinding

mills have been subject to the usual corrosion with which chemical industry is forced to deal. Mills have been designed and operated successfully where resistance to corrosion was a necessary consideration.

Equally as important as the factor of maintenance is the consideration of the properties of the final product. In some cases the aim is to eliminate the coarse particles without special attention to the fines, as in the raw mix for cement burning, and to a lesser extent in mineral fillers. In other cases the aim has been to develop surface, as with finished cement. Both aims apply to powdered coal. The value of the fineness of the finished product is being more clearly defined with the development of methods of measurement of sub-sieve fineness. The exact methods of measurement are somewhat laborious, but rapid methods have been developed which give indication of fineness of the final product. As yet, however, there is little exact knowledge of the relation of fineness distribution of the product to mill performance.

For many years the mining industry has operated mills in closed circuit. The wet sludge is passed rapidly through the mill, the fines are washed away, and the coarse material is returned for further grinding. Within recent years this general scheme has been used extensively when the product must be ground dry. Air may be passed through the mill; or the product, after

removal from the mill, may be air-separated into coarse and fine portions, the coarse in either case being subjected to further grinding. By removing the fines as rapidly as they are formed, and thus preventing mill coggage, air separators have revolutionized pulverizing methods. Mill capacities have been increased, power per ton of product lowered, and new commercial limits for fine grinding have been established.

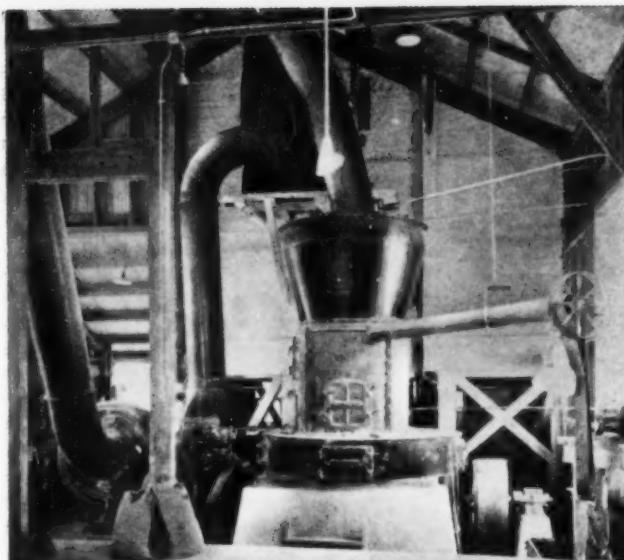
A consideration of mill design indicates that variations from the five types of milling action are uncommon. Within these types, however, new mills have been developed for improved operation. The direct-pressure mills, as jaw crusher, gyratory crusher, stamps, and the like, are designed for primary breaking or coarse crushing. As such they present chiefly the problem of securing capacity over a wide range of sizes. A tendency to enlarge the circumference of the discharge opening of the gyratory crusher has carried through to the design of a disk mill in which both faces operate at the same speed and in which crushing is produced by having one disk on an eccentric shaft, thus crushing by direct pressure.

Developments in the roller type have been largely with the ball and ring-roller mills. These machines are used for relatively fine grinding, especially in the field of coal pulverization, where values of from 40 per cent to 85 per cent through 200-mesh may be obtained. One manufacturer announces a tendency toward wider rings and heavier rolls, thus giving greater crushing capacity for a given size of installation and lowering the maintenance. At the same time, roller mills are appearing in small units to meet the demand for limited tonnage of fine products. A midget roller mill adaptable for pulverizing chemicals, dry colors, dyestuffs, clays, limestone, talc, and similar products at capacities of from 500 to 2,000 lb. per hour has been placed on the market.

The ball-ring mill operates by cen-

Ball-Ring Pulverizers. These Fuller-Lehigh Mills Consist of Separator, Pulverizing and Drive Sections





Pulverizing and Drying Barytes, Clays, Limestone, and Talc in a Raymond Kiln-Mill. This is a Typical Air Separator Scheme With Mill Drying

trifugal action of balls against the ring. The manufacturer of this machine has produced a new design resembling a ball-thrust bearing in which a positive spring pressure may be applied. It is asserted that this mill will pulverize coal of any hardness or grindability. As mills of the roller type operate at a few hundred revolutions per minute, the sealing of all bearings, gears, and the like away from the grinding zone is quite important, and it is being shown more consistently in newer designs. These mills were initially used with screens to hold back the product for complete grinding. They are now extensively swept by air with a separator in closed circuit for fine grinding.

Ball-and-tube mills have been outstanding where exceedingly fine grinding is necessary. In these mills the grinding parts are cheap, and the maintenance normally is low. The power to operate the mills is the major item of expense, and this power does not usually vary greatly from low capacity to high capacity. There is a tendency to increase the mill diameter in order to secure the accumulative weight of the ball charge in these mills. Diameters of 10 ft. are not uncommon. The random action of slugs or pebbles which characterizes these mills may be controlled to some extent by the use of a suitable size of ball for each stage of grinding. Large mills with as many as four compartments have been designed. The conical mill also appears to furnish large ball action at the center and small ball action at the end. Great attention is being paid to size and number of units for any given demand, to secure the minimum power cost per ton of product.

Manufacturers stress many different features of construction. For example, the conical-end mill is said to have less wear on the end plates. Several manufacturers stress the ease of replacement of liners, and also their long life before replacement is necessary. In one mill where open ends free of screens are

counted an advantage, mouthpieces with raised spiral windings are used to feed back into the mill any balls which fall into the opening. Another manufacturer aims at the same effect by using specially designed screens to return the oversize. Tube mills are particularly noisy. Where used for direct firing around a power plant they are not easily isolated from the other operations. One manufacturer has quite effectively reduced noise by insulating the shell of the mill with a soundproof covering. W. C. Weber ("Chemical Markets," April, 1930) describes a mill which is made resistant to acid by vulcanizing a rubber lining to the shell. This rubber lining is protected by wooden strips, and a Silex lining is placed within it. The shell is thus protected doubly in case the acid penetrates the Silex at any point of failure.

Air separator schemes in closed circuit grinding wet are being more extensively used with the tube mills. Outstanding applications of the former include the grinding of stones, coal, and finished cement. The wet grinding of cement raw mix has been done in closed circuit.

Impact or beater mills operate at relatively high speeds and are used for a limited amount of grinding or for disintegration. These mills must be kept in balance and must operate smoothly. Ball bearings are used to lower the power. The hammers are being made more wear resistant. One manufacturer drills a hole in each end of the hammers so that they may be used reversibly, thus giving longer wear. Mills of this type have been converted from the screen separator to air separator. There has been a distinct tendency to use small units for direct firing of coal to individual burners and for disintegrating small quantities of valuable products. In the reduction of dyes and dry colors, a small unit may suffice for several products. A type in which the case may be split open for washing is being advocated.

Machines of the revolving-plate type range from the disk crusher to the colloid mill. In the finest reduction, the problem is one of dispersion rather than grinding. Much has been done in the operation of these mills by choosing dispersing agents that best aid milling action.

Separator schemes as an adjunct to milling have already been noted. When the maximum size of the product is over 50 mesh, mechanically agitated screens are used. Many new designs have been developed in which the vibration of the screen is set to produce maximum capacity per unit of area and minimum screen clogging. The major new developments with fine products lie in the use of air separators. These separators operate to produce a coarse and a fine fraction by centrifugal action on an air stream containing the suspended solids, by changes in the direction of the flow of the stream in a stationary system, and even by direct settlement. In making possible new limits of fineness these separators have increased pulverizer capacities from 30 per cent to 300 per cent, with a corresponding increase in mill power and maintenance. Circulating loads of from 500 per cent to 700 per cent are used in the production of fines, and make possible a cooler mill.

To illustrate the difference between a ball mill grinding without an air separator and with it, the straight mill grinding produced a cement of 85 per cent through 325-mesh before the mill became clogged, while grinding with an air separator produced from 95 per cent to 99 per cent through the 325-mesh at even higher mill capacities. These accomplishments are largely in terms of sieve mesh, for the fines are removed as rapidly as they are formed, and are not further ground. Hence for a given sieve mesh, a separated product is likely to have a lower total surface than would be had by direct grinding.

When air separators are used, it has been found possible to feed materials of high moisture content into the mill, where they are dried by a stream of warm air passing through the grinding zone. In the development of powdered-coal firing of Scotch marine boilers, coal which dripped water from the feeder was successfully ground in an air-swept tube mill. A manufacturer of another type of mill states that by this method the product from filter presses has been ground directly without previous drying.

In general it may be said, with respect to air separators, that marked advances have been made in their construction and operation in the past few years. There is less tendency to undersize the separator, and a greater tendency to depend on it to keep the material of suitable fineness.

Thus it may be seen that the keynotes of modern mill design are: low power, low maintenance, and air separators to make possible new limits of fineness.

SUITING DRYING MACHINERY TO CONTINUOUS PROCESSES

By A. O. HURXTHAL

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◆ CONSTANTLY INCREASING emphasis on the use of continuous processes during the past few years has been responsible for the advent of numerous interesting new pieces of drying equipment. Dryer engineers are thinking more and more in terms of the dryer as one link in a chain of continuously operating equipment. This is by no means a recently acquired habit of thought, but it is one that has lately been responsible for marked progress in the development of machines capable of operating efficiently in conjunction with the process steps that must follow or precede them.

Drying on a continuous basis is rarely as simple as might appear on the surface. Many complexities must be overcome before a satisfactory continuous machine can be developed. What are

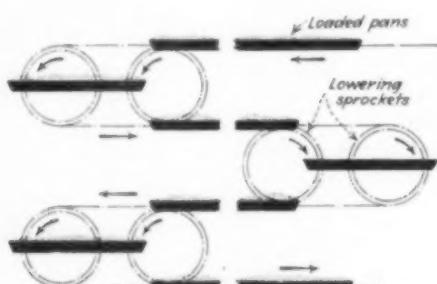


Fig. 1—Tray Dryer With Non-Tilting Pans

some of the requirements of such a dryer? The answer will in part indicate the lines along which the problem must be attacked and will assist in formulating a set of criteria for judging the design that results.

As a first requirement, the dryer must be capable of continuous operation, usually at a speed in synchronism with the rate at which material will come from an earlier process. The dryer must not become a bottle neck. Nor must it be subject to breakdown which may conceivably result in tying up an entire plant. Much more than in the case of intermittent apparatus, the continuous dryer must make possible sustained operation for long periods of time.

A continuous dryer must have a large drying capacity per cubic foot and per square foot of floor space. In the case of a cabinet dryer, material is simply held until it is dry. In a continuous

machine, it must progress steadily toward the discharge and yet remain in the drying zone long enough to accomplish the desired result. This capacity-per-unit-volume requirement has been responsible for a great deal of ingenuity on the part of dryer designers.

Constant and accurate control is a third important requisite. Since the time in the dryer usually is dictated by the rest of the process, if excessive handling and storage of materials in process is to be avoided there can ordinarily be no recourse to a change in speed when drying conditions are altered. This means that flexibility in the heating arrangements must be provided. It must be possible to increase or decrease the steam supply or the quantity of heated gases available. If necessary, the rate of air or gas circulation must be regulatable at will. And adequate control facilities must be provided to eliminate the fallibility of human operation as far as possible. In many cases it will be necessary to regulate not only temperature but the humidity as well.

In addition to these three prime considerations, there are other factors almost too obvious to call for comment. A continuous dryer must require a minimum of attendance. It must be economical in operation and reasonably easy to maintain. It should be of sufficiently standard design that its first cost will not be prohibitive nor the cost of replacement parts excessive.

There are, of course, a great variety of continuous dryer types. For bulk materials in large quantities, where there is little danger of overheating and where balling up and ring formation are not factors, the direct, indirect, and multi-pass rotary dryers are eminently satisfactory. Baffled tower dryers give good results in some cases for materials ordi-

narily handled in rotaries. Very dilute products, such as milk, are dried on drums or in spray chambers. Spray dryers have been found suitable also for much thicker materials, even approaching the consistency of mud. Where low temperatures are necessary, several types of vacuum dryer have met with much success. The present article, however, deals chiefly with equipment for those types of product which, lacking a continuous machine, have ordinarily been handled in tray and truck dryers. Such materials vary widely in their physical characteristics and range from fine granules to lumps, from thick, pasty masses to "soup" so thin that it must be carried in pans.

In the application in actual dryer design of the several criteria outlined above, it may be said that the first two, involving continuity of operation and

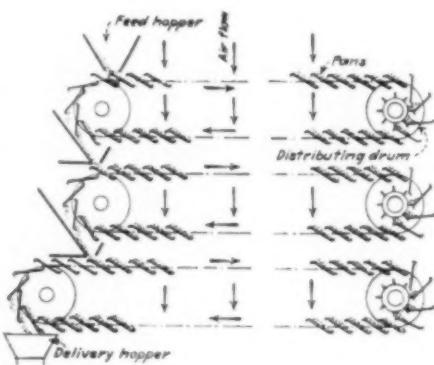
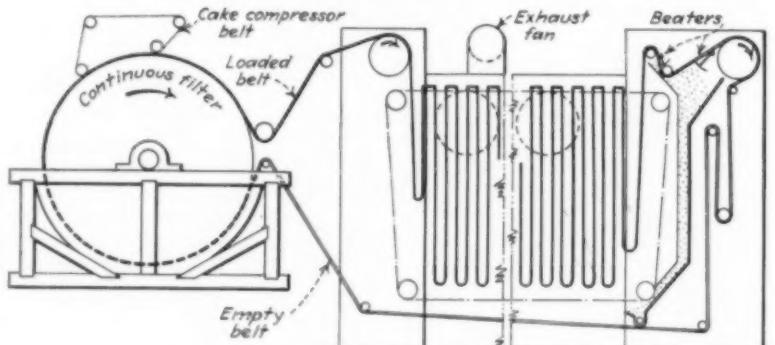


Fig. 2—Reversing-Pan-Conveyor Dryer

provision for drying a large quantity of material in a relatively small space, are the most difficult to attain. Use of standardized parts, so far as possible, is well known; and materials capable of insuring long life are readily obtainable, provided the designer does not skimp the requirements. Use of steam coils and fans of ample capacity should present no difficulties. Of course, care must be exercised in the proper location of heating units and in the choice of airflow direction. Both of these, however, are largely influenced by the type of construction used to meet the first two criteria. Required attendance also is conditioned by the same two factors and by the use of the reliable control instru-

Fig. 3—Combination Filter and Dryer for Cakes That Can Be Formed on the Filter, Within the Conveyor Mesh



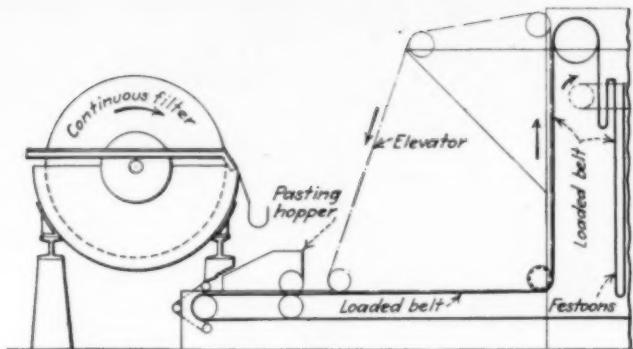


Fig. 4—Removing Materials From the Filter on a Dryer Belt, Where Pasting of the Cake Is Necessary

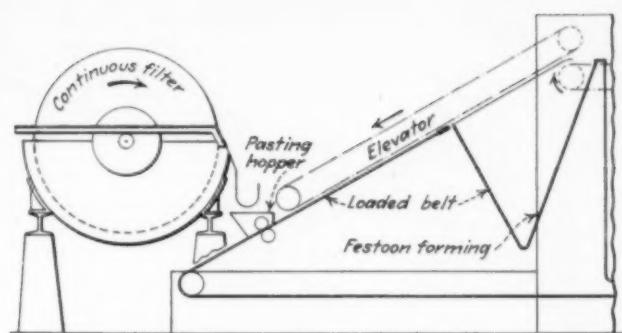


Fig. 5—Arrangement Suitable for Less Plastic Materials, Requiring Minimum Flexing of the Belt

ments now readily available. These questions of continuity and compactness also offer the greatest latitude to the designer, and the most fertile possibilities of failure.

A number of dryers designed in recent years by this company may be used here to illustrate the approach toward these problems. In the past, most granular and lumpy materials containing a high percentage of fines were of necessity dried in trays, on racks, or on trucks. For the continuous conveying of such materials through the dryer, wire-screen aprons were tried with excellent results from the viewpoint of drying; but frequently the loss of material through the screen condemned this practice. Canvas covers for the screens eliminated the dropping loss but necessitated air circulation across instead of through the conveyor and increased drying time two-, three-, or even four-fold. Such dryers were too large to survive.

Obviously some form of continuous pan conveyor, offering the least possible resistance to air circulation, was called for. The difficulty was to achieve both compactness and simplicity. The answer would seem to lie in a chain conveyor which could be doubled back on itself as many times as might be necessary to fulfill the requirements of compactness and capacity. Fig. 1 represents one type which meets the requirements. Here the carrying devices are trays suitable for fluid materials, as well as granular and lump products. At one end of each run of the chain, the double sprocket device lowers the trays to the next level without tilting. If desired, the tray contents can be dumped to the next lower tray at the end of each run. It is evident that the vertical dimension of such a machine is small compared with its capacity, and that it is very compact.

Still greater compactness for fine and lumpy materials is achieved in a very recent design shown in Fig. 2. The so-called reversing-pan conveyor is unique in that the trays are set at an angle, resulting in much higher holding capacity than can be obtained with horizontal trays, and at the same time permitting air circulation through the entire conveyor system. Due to its angle of repose, the material distributes itself

evenly over the trays and at the top end of each conveyor run each tray is automatically dumped onto the reverse side of a tray returning on the lower run. This constantly exposes fresh surfaces and, of course, hastens drying very considerably. [Editor's note—This new development will be described in detail in the equipment section of an early issue of *Chem. & Met.*]

So much for lump and powdered materials. When a product in the form of a slurry is to be recovered, the first obvious step is to filter. How to transfer the filter cake continuously and automatically to the dryer, and how to carry it through the dryer, has presented some

passes completely around the filter drum and the cake is formed within the meshes. A continuous pad compresses the moist solids into the mesh to form a firm, continuous cake which may then be carried in festoons through the dryer. After the dried cake has been broken loose by a beater the belt returns to the filter.

Where characteristics of the cake make this method undesirable, as for example in cases of poor compacting quality, where a belt such as that of Fig. 6 (c) is required, another method of pasting must be used. In Fig. 4, the filter discharges down a chute into a hopper above the belt, where rollers ac-

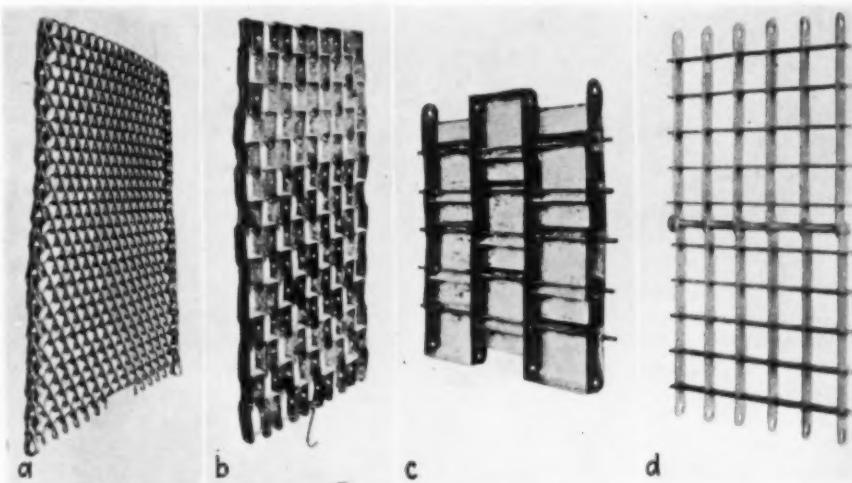


Fig. 6—Typical Steps in Dryer Conveyor-Belt Evolution: (a) Spiral Woven-Wire Belt; (b) Heavy-Duty Pressed-Metal Belt;

(c) Backed Belt for Less Plastic Materials; (d) Heavy-Duty Belt for Clays and Cement Materials Dried at High Temperatures

very interesting problems. Several variations of the solution, which have been worked out with the co-operation of Filtration Engineers, Inc., under basic patents held by that company, are shown in Figs. 3, 4, and 5. In each of these methods, the filter cake is compressed or pasted into the mesh of a continuous metal belt, such as one of those shown in Fig. 6, like so much mortar troweled into a metal lath. After the material has been conveyed through the heated chamber in festoons and fully dried, it is then released from the belt and discharged in lump condition by means of a chute and a conveyor. In the dryer shown in Fig. 3 the flexible metal conveyor belt

accomplish the pasting. Formation of festoons is identical with the method of Fig. 3. To insure even festoons, end extensions on girts at intervals in the belt are provided to engage the dryer chain. A similar arrangement may be seen in Fig. 5. Here, however, the object is to flex the belt as little as possible in forming the festoons, for use in those cases where the wet material is not very plastic. A chain elevator folds the belt so that the greater part of the flexing is localized in the center of each loop.

Satisfactory application of such methods, of course, is predicated on the development of suitable conveyor belts. As an illustration of the evolution of these

belt, Fig. 6 is appended. The earliest of these, the spiral woven-wire belt at the left, is reinforced on the edges with chains. Its field is the lighter job at lower temperatures. The second is formed of pressed metal for heavy duty and high temperatures. Neither is suitable for materials that bond poorly, and for such cases the backed belt of Fig. 6 (c) has been designed. The final development for very heavy duty at extremely high temperatures is shown at the right. It is suitable for drying heavy clays or filtered cement slurry, utilizing waste kiln gases.

Web materials, such as fabrics and paper, involve a totally different set of problems. The classical methods in continuous dryers have been those employing either the festoon or the roller system. The former required sticks for carrying the festoons and these, unfortunately, left stick marks on many ma-

terials. The latter, on the other hand, made no allowance for shrinkage. Here the problem was to obviate the disadvantages of both by combining the two types, and the resulting design (see *Chem. & Met.*, page 105, February, 1931) permitted complete control of expansion through the use of floating rolls of any desired weight, and yet eliminated stick marks. This has been accomplished by slowly rotating the festoon-supporting rolls so that for every hundred feet of web discharged from the dryer, the web travels from 3 to 5 ft., over the rotating festoon supports. Since no one part of the web remains in contact with the rolls, stick marks are impossible. This discussion has necessarily been very brief, but it should be sufficient to show that a proper and well-considered analysis of the problem can usually be expected to yield a design entirely suited to the requirements.

static, or rotary scrubbers are used with tar oil, gas oil, or water-gas tar as the scrubbing liquid for the removal of naphthalene, while cyanogen compounds are eliminated by means of the rotary or centrifugal scrubber. Centrifugal absorbers have found diversified application. A number of different absorbing solutions have been used, but the most common are those of either sodium carbonate, ferrous sulphate, or alkaline solutions of ferrous sulphate.

For use with solid absorbents, the equipment has generally assumed the cylindrical tank form. Particular attention has been paid to the size of the granules of the absorbent and their arrangement in the chamber so that low gaseous pressure drops and "channeling" may be avoided. Some activated carbon absorbers have been built of steel with Bakelite linings.

In the September, 1928, issue of *Chem. & Met.*, E. M. Baker reviewed the progress in theory and practice of gas absorption and adsorption. For many years practice outstripped theory. In 1928, Lewis and McAdams (*Ind. Eng. Chem.*, Vol. 20, pp. 253-57) presented graphical methods of design for gas-absorption equipment which were based on accepted theories. These graphical methods lessen the labor of computation and make possible correct solutions when curves expressing the equilibrium concentrations in the gas and liquid phases are of irregular shape. Lewis (*Chem. & Met.*, Vol. 35, pp. 93-5; 1928) applied the graphical methods to the design of natural-gas gasoline absorbers and was able to calculate satisfactorily the absorption of each of the several hydrocarbons involved.

It is now generally agreed that the controlling factor in the rate of absorption is the diffusion of the absorbed material through two films in series; namely, the films of gas and of liquid on the two sides of the interface between the phases. Sometimes the problem is simplified by the fact that the diffusional resistance of one of these films is negligible compared to the other, but often both films are important. Hanks and McAdams (*Ind. Eng. Chem.*, Vol. 21 pp. 1034-39; 1929) adapted the laws expressing the rate of diffusion of one gas through another to the absorption of a soluble gas from an insoluble one by a liquid. Equations were developed to express the influence of the major variables normally encountered on the rate of absorption of gases by liquids in a given type of apparatus where gas-film diffusion controls the absorption rate. Colburn (*Ind. Eng. Chem.*, Vol. 22, pp. 967-70; 1930) showed that in processes such as the absorption of soluble gases and dehumidification, the rate of mass transfer is dependent on the rate of diffusion of molecules through a viscous gas film adjoining the liquid surface and on eddy currents in the turbulent portion of the gas stream.

PROGRESS IN ABSORPTION AND ADSORPTION

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◆ DURING THE LAST THREE years, advances have been made in absorption theory, particularly from the mathematical and design side, and absorption practice evidenced in new applications for some of the solid absorbers and the development of new processes involving the use of new liquid absorbers.

Most of the equipment for absorption had its origin in connection with the manufacture of city gas, where, in the early stages of the industry, a small quantity of impurities had to be removed. The absorption equipment may be divided into four general types, consisting of tower, static, rotary, and centrifugal forms. The original scrubber, or absorber, consisted of a steel tower filled with various materials to break up the upward stream of gas and to increase the surface covered by the scrubbing liquid that was sprayed into the top of the tower and passed downward by gravity. Coke, quartz, numerous forms of wooden trays, boards set on edge, rock, limestone, and many manufactured special packing tower shapes have been used for this purpose. Designs were made in packing material so arranged as to obtain minimum pressure drop of the gas during its passage through the tower. On the basis of its cubical capacity, this type is the least efficient, but if built quite high it is

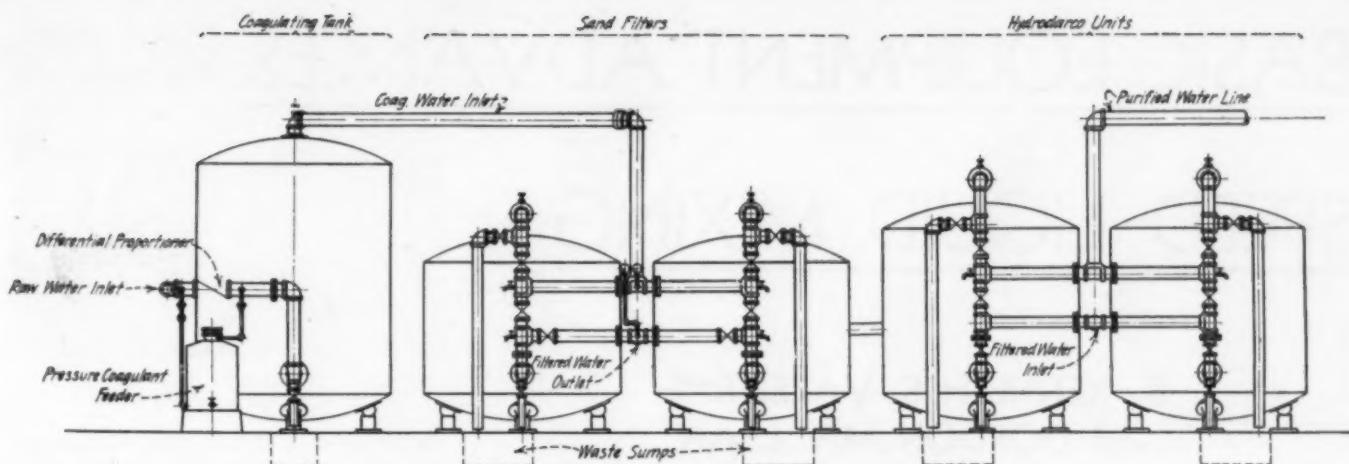
fairly efficient per square foot of ground space required.

In the static type of absorber, the gas is forced to pass in contact and bubble through the scrubbing or absorbing liquid by a series of partitions arranged across the flow of gas in a rectangular containing vessel. Another series of divisions permits the leveling of the scrubbing liquid to be regulated in the numerous compartments.

The rotary or mechanical type of scrubber is composed of horizontal cylinders divided by a number of vertical partitions. A central shaft carries a disk made up of a large number of short wooden rods set parallel to the axis of the shaft and arranged so that as they revolve they dip into the contents of the scrubber, and on rising present a large wetted surface to make contact with the stream of gas. As the result of their revolution, the gas stream is broken up by the mild fan action.

The centrifugal type of absorber is of more recent development. A typical example is the Feld scrubber. In this the scrubbing liquid, in descending from one compartment to another, is thrown into a sheet of spray by the action of revolving cones attached to a central shaft. The central shaft is driven by gearing at the base of the machine. The cones or baskets are of perforated metal. The gas enters at the bottom of the unit and is forced to pass through as many sprays as there are sections of the apparatus.

In city-gas manufacture, the tower,



An Activated Carbon Installation for Filtration of Water, Consisting of Pressure Coagulating Tank, Pressure Filters, and Hydroarco Purifiers

An equation was derived for mass transfer from fluids in turbulent motion and experimental data agreement found for both dehumidification and absorption.

On an industrial scale, the absorbing materials which have received most attention are the various earths such as diatomaceous and fullers earth, the activated carbons, silica gel, activated bauxite, numerous chemical solutions, and synthetic products, among which is triethanolamine. Improvements have been made in more efficient equipment employing the bleaching earths and clays, as well as the development of better regenerative processes.

Activated carbons have found increasingly wide usage in decolorizing products such as the vegetable oils, organic and inorganic acids, sugar, food products, as well as decolorizing and deodorizing of inorganic chemicals. A new important development which promises to consume increasing tonnages of the activated carbons is in the removal of odors and tastes from potable water. Commercial plants are operating for the elimination of tastes and odors due to residual chlorine, phenols, chlorophenols, and other byproducts existing in small quantities as the result of manufacturing plants whose wastes eventually find their way into water supplies.

The industrial equipment which has been developed is of two types. In one the carbon employed is finely divided and light. It is fed into the water in amounts from 0.05 to 0.15 gr. per gallon and later settled out in settling basins after it has done its work. In the other case, the carbon is granular and is used in a filter bed. The use of carbon allows overchlorination for complete protection against seasonal increase of pathogenic bacteria, and dechlorination at a low cost. The carbons employed for water treatment are modifications of those used for decolorizing.

Activated carbons of the gas-absorption type have found a greater number of industrial applications in Europe for operations such as the recovery of benzol from coke-oven and manufactured

gases, the removal of hydrogen sulphide and sulphur compounds from industrial gases, particularly those employed in high-pressure syntheses; while in this country more intensive work has been done in the purification of carbon dioxide, particularly for beverage purposes, and the elimination of stenches and odors. In the United States, South America, and abroad, there has been an increasing development and utilization of activated carbon for the recovery of gasoline from natural gas. Reich (*Chem. & Met.*, Vol. 38, pp. 136-41; 1931) has described the activated carbon method of purification of carbon dioxide for beverage purposes as well as its competitor employing silica gel. Uhlig reviewed absorption processes in the gas industry employing carbon (*Chem. & Met.*, Vol. 35, pp. 580-1; 1928). Development has continued in the purification of gases by absorbing hydrogen sulphide and sulphur compounds from them and oxidizing these to sulphur by the catalytic action of the carbon. The sulphur is recovered by extraction with a solvent and the carbon revivified.

The refining of light oil with silica gel was described by Fulreader (*Ind. Eng. Chem.*, Vol. 21, pp. 691-3; 1929), and the extraction of high sulphur oil from crude petroleum by the same reagent by Woodward (*Ibid.*, Vol. 21, pp. 693-5; 1929). Reich has described the use of silica gel for the dehydration and purification of carbon dioxide. While in the case of activated carbon, absorbers are periodically steamed to revivify them, this cannot be done with silica gel, as this material is a dehydrating agent. Reactivation is therefore done wth a current of heated air. Large amounts of development work have been done on silica gel as an absorbent in refrigeration cycles. Systems of this type have been applied to refrigeration of freight cars where Pyrofax gas was employed as the means of supplying energy to the system.

Activated bauxite has been prepared on an industrial scale as an absorbent finding application for the removal of

moisture from air, particularly in connection with air blasts through cupolas and furnaces.

The scope of gas purification has been enlarged as the result of the demand for pure gases for use in syntheses. The cost of these purification processes has placed a premium on those which recover useful products. Liquid absorption methods for gas purification have been recently developed. Byproduct coke-oven ammonia has been employed as the alkaline-absorbing medium for acid vapors, but its high vapor pressure is a disadvantage. Other processes have been put in practice, based on the use of a weak solution of soda ash for the absorption and recovery of hydrogen sulphide and carbon dioxide, and continuous processes developed.

Triethanolamine, $N(CH_2CH_2OH)_3$, is an organic base which is alkaline and reacts quantitatively with acids and acid-forming gases, as well as being soluble in water in all proportions. Unlike ammonia, it has a low vapor pressure and a high boiling point. Unlike sodium carbonate, which can be used only in dilute solutions, triethanolamine can be employed in any concentration. It has been suggested and applied in the absorption and recovery of carbon dioxide from flue gases and the removal of this constituent from gases used in the syntheses of ammonia and methanol. The absorption and recovery of hydrogen sulphide either as such or as sulphur, and many other applications have been suggested. Neutral salts of triethanolamine are quite stable, whereas the acid ones are readily decomposed thermally in the presence of water. The triethanolamine radical, both free and combined, is stable and the vapor pressure of the material, both free and combined, is low. The material or its useful salts may be regenerated from any combination occurring by reaction with the usual acid vapors. It is manufactured by the Carbide & Carbon Chemicals Corporation and its use in gas purification processes is controlled by patents of the Girdler Corporation.

BASIC EQUIPMENT ADVANCES

SPEED LIQUID MIXING

By KENNETH S. VALENTINE
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◆ ALTHOUGH NO FUNDAMENTALLY new type of mixer has appeared within the past decade, the demand for improved equipment has led in recent years to the creation of what has amounted, practically, to a number of new forms. These designs have evolved from existing mixers, but many of the advances have been of basic importance and have contributed largely to the success of new industries and the greater efficiency of old, particularly in the cases of pyroxylin lacquer manufacture and petroleum refining.

Before passing to the six fields in which these advances have taken place, it is desirable to define the fundamental aims of the designer of mixing equipment and the principal lines along which these aims have led him. First, it may be stated that liquid mixing embraces the mixing of liquids of all viscosities and consistencies with other liquids, solids, or gases. The object may be to produce a blend, a dispersion or emulsion, a solution, a suspension, or to effect a reaction by bringing the reacting components into the most intimate possible association. Hence two

general rules must be fulfilled in the majority of mixing problems: (1) The mixer must be capable of producing a degree of mixing sufficient to yield the desired results. (2) It must establish and maintain a satisfactory rate and direction of flow within the *entire* body of liquid, however remote from the mixing element, so that all of the material may be mixed sufficiently within the optimum time.

Intimacy and degree of mixing depend either on actual physical contact between the ingredients of the mixture and the mixer itself (of which the container should always be considered a part); or on turbulent flow of the mixture ingredients. The effect generally is most pronounced in the vicinity of the mixing element, for liquid velocities are highest in that region. A substantial part of the total power input is expended in bringing about this intimacy of mixing, while the remainder is utilized in producing and maintaining the necessary flow.

Producing the desired flow so as to mix the entire liquid body uniformly and thoroughly is equally important. Stratification and settling will render the results of an otherwise perfect mixer quite worthless. Unless both horizontal and vertical flows are sufficient, and unless *all* of the material in the container is moved *repeatedly* into the zone of intensified action, whatever mixing, break-up, dispersion, or solution takes place there will be completely nullified. This point cannot be too strongly stressed, for it is often neglected, with disastrous results to yields and time consumed.

Once the designer has chosen a type of mixer meeting the requirements of the two fundamental rules, he has further to consider such matters as materials of construction, capacity, size, operating speed, and power consumption. It is, unfortunately, impossible to set up definite rules covering all these points, although a number of general statements may be advanced.

On the question of materials of construction, it may be stated categorically that every possible condition can be met, although some compromise with long life, mechanical efficiency, or time of mixing may be necessary in cases of the most drastically corrosive liquids. In most basic mixer types, possible construction materials range from any metal or alloy capable of fabrication by



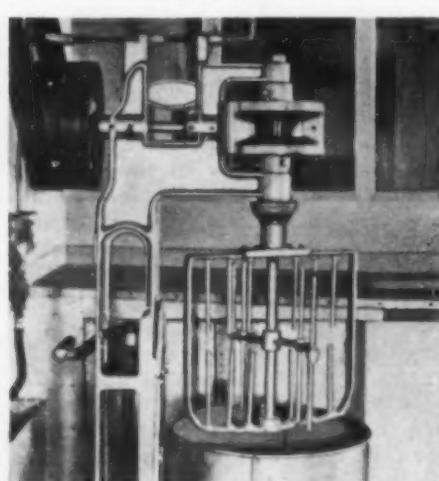
Fig. 2—Glass-Lined Tanks Equipped With Propellers Driven Through the Side of the Container

casting, welding, forging, or riveting to non-metallic materials such as stoneware, resinoids, and hard rubber; or metals covered with rubber, glass enamel, resinoid varnishes, or other metals. Wood is satisfactory for some of the simpler types. Where abrasion is a serious factor, rubber coverings or hard facings are often applicable.

Mixing capacity cannot, in general, be safely predicted on a purely theoretical basis. It will depend on the type of mixer, its capacity, and its speed of operation. Neither is power consumption, which depends on the same factors, subject to accurate prediction. An empirical background is necessary, therefore, before any satisfactory mixer can be developed.

At this point the five fundamental mixer types should be examined. One of the oldest forms is the simple paddle mixer. Modifications include the ordinary gate type and a more recent form in which two sets of vertical or horizontal members rotate in opposite direc-

Fig. 1—Modified Paddle Mixer for Pastes, Using Two Elements Rotating in Opposite Directions



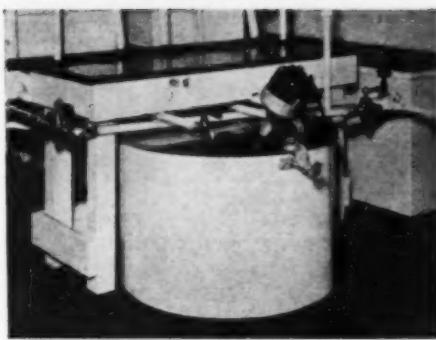


Fig. 3—Portable Propeller-Type Mixer Which Clamps to the Tank Side

tions, one driven from an inner solid shaft and the other from an outer, hollow shaft, which surrounds the first. The mixer shown in Fig. 1 is an example. The horseshoe type is a modified paddle mixer which finds application in round-bottom vessels. All such mixers have flat or angled blades, which usually are driven at low speeds, with tip velocities ranging from 75 to 350 ft. per minute.

A second fundamental type includes all mixers which rely on a pump located outside the container. This often is a centrifugal pump drawing material from the bottom of a tank, preferably equipped with a cone bottom, and distributing it at various points on the surface.

The third general class includes all kinds of propellers. The permanently installed propeller of Fig. 2 and the portable mixer in Fig. 3 are examples. Propellers may be mounted either singly or in multiple on a shaft. They may produce either uni-directional flow or opposed flow, the latter called "push-pull." They are often mounted within a draft tube or set off-center in the tank to prevent mass rotation. Their peripheral speed usually ranges from 1,000 to 2,000 ft. per minute.

Turbine mixers, three variations of which appear in Figs. 5, 6, and 7, form a fourth class. They are similar to centrifugal pumps, but lack casings and are arranged to rotate horizontally within a tank on a single vertical shaft. They may or may not be provided with deflecting baffles around the impeller to prevent swirl and promote radial flow. A typical apparatus is a dish-bottom tank, with two or more impellers on one vertical shaft, driven at a peripheral speed of 600-900 ft. per minute.

The final classification includes colloid mills and homogenizers. Although these machines fulfill none of the conditions relating to flow set up by the second fundamental rule given above, they are nevertheless designed to effect a maximum of break-up, dispersion, and emulsification, as well as a degree of disintegration impossible in most cases with other forms of mixer.

It was suggested earlier in this article that recent design improvements have had six principal objectives. In summary, these include improved drive;

increased ease of operation; ability to mix larger batches; capacity for mixing and dissolving materials of higher viscosity, or greater consistency; improved dispersing ability; and adaptation to continuous processes. The first of these objectives is evidenced by a decided swing toward the inclosed drive. Certain makers have discontinued the open drive completely, with consequent greater safety and quietness and superior lubrication. The new drives avoid contamination of the product with lubricant and of the lubricant with dust. Anti-friction bearings are being used much more extensively, as are individual motor drives. In certain cases, where variable speed is required, steam turbines with multiple V-belt drive are employed. On the score of greater ease in operation, the spread of individual motor drives may be adduced. Increasing use of portable mixers similar to the one in Fig. 3 is also worth mentioning, as they have contributed greatly to convenience and to improved mixing of products that were formerly neglected or hand-paddled. Such mixers consist of propellers or turbines on a shaft, driven direct or through reduction gears by a vertical motor. The whole is arranged for clamping to the side of a tank. A folding propeller type is now made which may be inserted through the bung hole of a drum.

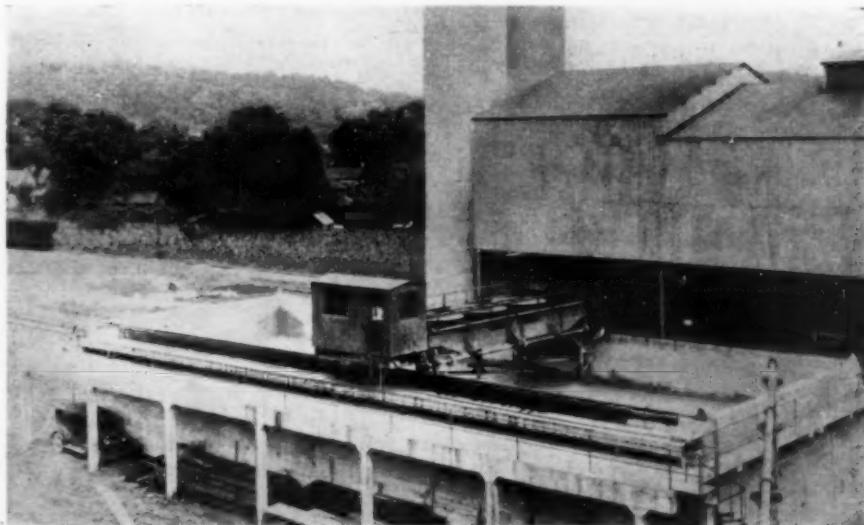
Superior methods have been devised for the agitation of gigantic batches. For instance, a useful modern development consists of a traveling paddle agitator built on the principle of a traveling crane. It is used to keep in suspension huge batches of paper pulp or cement slurry of moderate consistency. One of these machines built for cement plant use appears in Fig. 4. The mixer mechanism travels back and forth on rails over a huge tank, sometimes as large as 100 ft. x 25 ft. x 20 ft. deep. The solids are kept sufficiently well suspended and some transportation and intermixing are obtained at very low power cost per ton. Quick mixing

is not a factor here. A second recent development is used in paper mills for producing pulp suspensions. It consists of a continuous oval tank shaped like a beater, but lacking the beater roll. Instead, at each end of the tank there is a partition, in the center of which a propeller is mounted. Rotation of the propellers keeps the stock circulating, and at the same time, through its pounding action, reduces and hydrates the pulp. This machine decreases time in the regular beaters, or may even make it possible to send the stock directly to the jordans.

Another propeller agitator, suitable for thin liquids, is used in blending large batches of light solvents in tanks 30 ft. in diameter and 20 ft. deep, using a small propeller about 12 in. in diameter. The shaft extends horizontally through the side wall at an angle oblique to the tangent at the point of entry. Mass rotation of the contents is induced and enough interferences are created to mix the contents slowly in several hours, with an absurdly small and inexpensive mixer.

Very significant progress has been made in mixing and dissolving materials of high viscosity and consistency. Much of this progress has centered around the turbine mixer, because it has shown itself well adapted to producing flow, circulation, and dispersion in highly viscous materials. This is explained by the fact that the turbine type is the only truly three-dimensional mixer. Vertical currents are drawn into the device and horizontal currents are expelled and distributed radially to all parts of the container, thus bringing every particle into circulation. The change of direction does not, as in the propeller type, depend on deflection from the walls or bottom of the container, where poor direction and lowered momentum result. On the contrary, change of direction takes place within the turbine itself; and, because the device is a centrifugal, the maximum liquid momentum is not developed until the very point of dis-

Fig. 4—Smith Traveling Agitator Installed in a Cement Slurry Tank



charge is reached. This means that the directional change is accomplished at low velocity and the radially issuing currents may be trained on the remote portions of the container with undisipated energy. Consequently, neither time nor energy is wasted in reaching the far corners and a very thorough job can be done.

Such action is required in highly viscous materials. Turbine mixers, of course, will not function if the viscosity becomes so great that a depression in the surface of the material will not fill; but for lesser viscosities they have been very successful. Their use in the pyroxylin lacquer industry illustrates the point. Here it is necessary to dissolve nitrocellulose in solvents and subsequently to pigment the clear solution. Viscosity is likely to be extremely high. A turbine dissolver (Fig. 5) was developed especially for this work and required only 15 or 20 minutes to complete the dissolving operation, a reduction in time in various cases to between one-third and one-twentieth of that formerly needed. At the same time, the work could be done with a smaller motor than usually was required by former practice. A comparatively flat, wide container with a dish bottom was used, so that currents starting from the single large turbine would already be moving in an upward direction when the side walls were reached. The turbine had large orifices and high volume capacity and imparted a brisk radial movement, even to heavy "dopes." The deflector blades were set far apart, so as not to interfere with the flow. Each blade was equipped with grater plates or small teeth for eroding the solid or gelatinous pieces, thus aiding more rapid solution.

A similar machine proved to be equally satisfactory in the photographic and artificial leather industries and in dissolving gums such as damar, copal, and shellac. A modified type of turbine mixer for viscous materials is used in mixing clay and fullers earth with cylinder stocks and lubricating oils before contacting. It has been shown

that the turbine is capable of giving practically instantaneous wetting and distribution of the clay as fast as it is fed to the batch, even with viscosity above 5,000 seconds Saybolt.

A fertile field for mixing development has been in connection with breaking up, dispersing, and emulsifying of two or more immiscible liquids, or of a solid or a gas in a liquid. Propellers, producing as they do a high rate of shear when rapidly rotated, have recently proved themselves useful for obtaining fairly intimate intermixing and, in many cases, a satisfactory emulsifying of immiscible liquids. Examples include the making of automobile and furniture polishes. This same principal is used also in treating processes in the petroleum industry.

Turbine mixers have been used very satisfactorily in cases where a higher degree of action is required. The turbine type is essentially a disperser, and this tendency is still further aided by the fact that the discharged particles have to impinge forcibly against the deflecting-ring blades while traveling at their maximum velocity.

Many cases of reaction between a gas and a liquid, including oxidation, hydrogenation, and chlorination, have been intensified and speeded up with special types of turbine mixer. The device shown in Fig. 6 is an example. Here a draft tube fitting rather closely about the intake of the lower turbine causes the latter to act as a pump on the liquid about it. Gas blown into the top impeller through a distributor ring, or sucked into it through a hollow shaft by the rotation of the impeller, is dispersed with the liquid and discharges as a fine mist around the turbine periphery. Downward-directed deflector rings send gas and liquid over a circuitous path into the lower impeller, whence the intimate mixture flows outward and toward the surface. If the gas is not then spent, it may be recirculated.

Equipment of this type used for oxidizing asphalt with air was able to reduce the treating time from four to two hours, while its utilization of the

oxygen in the air supplied was double that of the earlier process. In another case, a difficult hydrogenation, the turbine completed in two hours what a propeller mixer had failed to accomplish in 50 hours. More thorough dispersion was responsible for the improved results.

Equally good dispersion has been attained in mixing immiscible liquids and liquids with solids. Many petroleum refiners have adopted turbine-type treaters within the past two years for acid and caustic treatment of various light fractions, as well as viscous lubricating oils. Because of the high rate of circulation (which may amount to over 12,000 g.p.m. in a 500-gal. treater) and because of a high degree of dispersion and intimacy of contact, both time and the quantity of reagent have been materially reduced. In one case a low-grade lubricating oil, which had previously required 60 lb. of sulphuric acid per barrel, was treated satisfactorily with less than 40 lb., and a free-flowing sludge was produced. In another case, a turbine treater reduced the clay used in treating a heavy oil by more than 20 per cent. The only possible explanation for these results lies in thoroughness of dispersion.

On the other hand, where the finest of dispersions and emulsions is required, as in certain asphalt emulsions, emulsified insecticides and superfine paints and lacquers, the colloid mill is clearly called for. Such products have been made possible only through the use of the colloid mill.

As the last of the six fields of developments, we mention continuous processing, which probably has been the most pronounced trend in chemical industry in recent years. Mixing equipment has necessarily made many advances along these lines, and these advances have, in turn, been important factors in the success of the processes themselves. In all cases, a small compact unit which will permit large throughput while assuring the required holding time is the most desirable mixing machine.

Fig. 5—Turbine Dissolver of the Type Used in the Pyroxylin Lacquer Industry

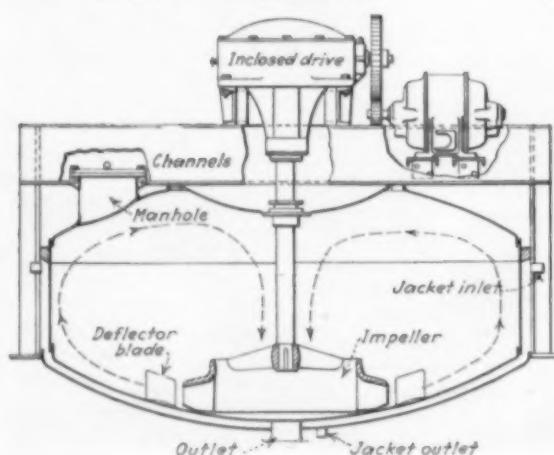


Fig. 6—Turbine Disperser for Thorough Mixing of a Gas and a Liquid

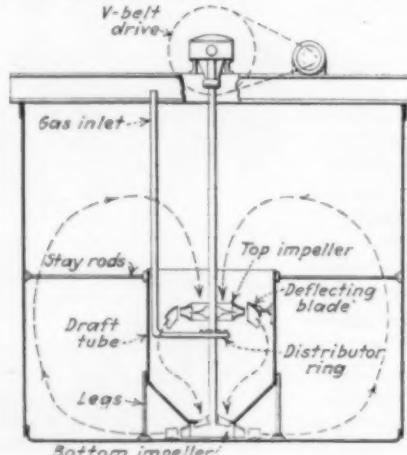
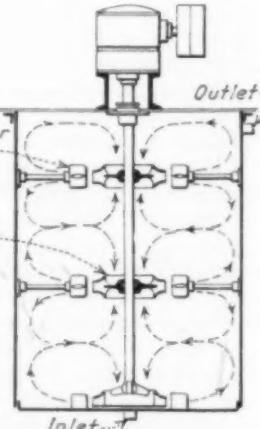


Fig. 7—Continuous Turbine Treater for Mixing, Dissolving, and Dispersing



Satisfactory blending results have been attained continuously with light mixtures by running them through a centrifugal pump in the right proportions. Somewhat heavier materials, such as hot asphalts and lubricating oils, have been blended continuously by passing them through a small tank or tube equipped with propellers. More difficult problems of continuous processing, however, require turbine mixers. These include very rapid, large-scale operations, such as the mixing of dry solids with liquids, the dissolving of solids in liquids, the dispersion of immiscible liquids, and the dispersing of gases in liquids. The usual result is greater economy than has previously been possible, either in holding time, equipment size, reagent consumption, or power consumption.

Such a continuous machine for dispersing, dissolving, or mixing appears in Fig. 7. Materials enter at one end and the mixture is taken off continuously at the other. In traversing the mixer, every particle must go at least once through each impeller, from which it travels to the next by a long, circuitous path. Striking instances of the use of this device are available. In one refinery a 50-gal. continuous treater handles 20,000 gal. of lubricating oil and sulphuric acid per day with a 30 per cent reduction in the acid formerly re-

quired. This sort of work cannot be done in an orifice column. Another continuous treater reduces sulphur in a pressure distillate to the desired figure, using 18 per cent less acid than was required by the refinery's most efficient orifice mixers. About 3,000 bbl. of pressure distillate per day can be treated with one minute of holding time, which usually is sufficient for a continuous treater of less than 200 gal. capacity. As the equipment operates without back pressure, the power consumption is only one-sixth of that required to force the distillate through an orifice column.

Other examples are numerous, but a few will suffice. A 250-gal. continuous machine is mixing and dispersing 350 lb. of clay in 1,000 gal. of oil each minute. A 2,000-gal. mixer in the paper industry consumes 10 hp. and is capable of diluting uniformly 1,000,000 gal. of stock per day. A 200-gal. mixer consuming 2 hp. dissolves 10 to 20 tons of a salt per hour, and produces continuously a cold saturated solution. The difficulty of this accomplishment can be appreciated when it is considered that the same operation on a batch basis will require a great deal more time and very much larger apparatus. Such cases are merely cited to prove that research applied in the province of mixing has enabled it to keep abreast with the demands of industry.

of the prime considerations should be the shape and speed of the agitators. When all the data available regarding the mix have been obtained, the first step in design should be to compute the blade resistance and the work to be done. This must then be translated into the required motor horsepower for every stage of the process. The power requirements, therefore, are the starting point from which to compute the stresses on the shafts, the bearing pressures per square inch of projected area, the gear tooth velocity, the gear strength, and last, but certainly not least, the lubrication requirements.

I have in mind one case which very well illustrates the probable results when these things are not given due consideration before a mixer is chosen. The superintendent in the plant in question was hampered by a very small appropriation. It resulted in his buying a certain mixer largely because it was quoted at a lower cost per pound than any other machine offered by the several manufacturers who were bidding. After two years of use, the mixer had cost more in maintenance than its original price. When I was asked to analyze the tooth loads, bearing pressures, and stresses throughout the machine, I found that it was impossible, under the bearing loads imposed, to keep an oil film between the shafts and bearings. Satisfaction could never have been obtained, no matter how many replacements were made. This emphasizes the fact that any purchaser of mixers will be wise to inquire the maximum horsepower for which the machine is designed, the bearing pressures in the slow-speed shafts at peak load, and the type of oil required.

Heavy-duty mixing has now progressed to a point where practically any combination of conditions can be met. For instance, the mix may be both abrasive and strongly acid, and run the entire range from liquid to solid and finally granular. In a mixer built for just this service a pair of specially treated arms was run against a pair of ordinary cast-steel arms, with the result that the life of the former was found to be fully four times the latter. In this machine it also was necessary to prevent the shaft packing from becoming charged with the abrasive material. Bearings had to be removed from possibility of the same difficulty.

This is mentioned to impress the fact that someone has to think before a purchase can be made. Thinking after the purchase is all too likely to be a very expensive proposition. The day has arrived, I believe, when important installations of this kind can be made satisfactorily only through utmost frankness on the part of the purchaser and through conferences between those interested in the operation of the equipment and those who are best able to advise concerning the design features that must be provided.

HEAVY MIXING NEEDS MUST CONTROL DESIGN

By A. O. RUSSELL

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◆ SELECTION OF A HEAVY-duty mixer is likely to become a real problem, especially when a new product is involved. This may be one requiring temperature control, periodic sampling, processing under pressure, or other features which greatly complicate the design of a suitable mixing machine. For such a case a standard design may very probably be unsuited and the purchaser of one of these can consider himself fortunate if the results equal his expectations. His better course is to delve thoroughly into the details of his requirements, not merely as regards superficial information such as bowl capacity, price per pound, and so on, but to consider fully such questions as the necessary life of the machine and the exact duties it is to perform.

It will be surprising to many engineers to learn the vast difference that

the proper shape of stirrers or blades can make in the operation of a mixer. After many years of experience with heavy-duty mixing I have come to the conclusion that there is one best blade shape and blade speed for the most economical handling of any given mass or group of masses. In dealing with liquids that remain fluid, this does not obtain, but in the case of masses which may change their viscosity or may run the entire range from liquid to semi-solid during the mixing period, it is very much the case. It would obviously be wrong to provide blades with contour and speed suited to the liquid stage of the mixing. Such blades would be too flat and would offer too much resistance when the semi-solid stage was attained. The very high peak load that would be reached would require shafts and bearings out of all proportion to the true needs of the process. Power consumption would be much too great.

In mixers of the double-arm type, one

DESIGNING POWER SERVICES

FOR PROCESS PLANTS

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◆ POWER-SERVICE SUPPLY FOR the process industries presents many unique problems, as each manufacturing establishment's requirements are individual, yet many opportunities exist for developing remarkably inexpensive services. In a measure, somewhat different discretion is called for in their development from that which is customary in the strictly electrical power industry, yet the problems in both industries have much in common. The judgment exercised in designing a central station is motivated by the desire to render the best possible service without interruption to continuity, at the lowest possible cost within economic limits. In developing an industrial power plant, the judgment used to attain the same objective must needs be tempered by determining what degree of perfection is warranted to secure the best economy, weighing carefully the value of increased reliability and additional capacity versus the expense of obtaining greater perfection. Balancing quality against cost of power services is of fundamental importance in the process industries today, when competition is so keen and many operate on a very narrow margin of profit.

Whether one shall generate or purchase services is a most interesting question and no preconceived answer should be given. A detailed study must be made of the potential economic possibilities of each case as it is presented. Some fundamental considerations will be outlined as a guide in determining which source is desirable under certain conditions. In general, though, the steam and electrical needs in the majority of cases bear a more or less fixed ratio and are susceptible to balancing, in which instances generation in some measure is justifiable and the construction of a power plant is warranted. Assuming such is true, advantage should be taken of byproduct energy generation.

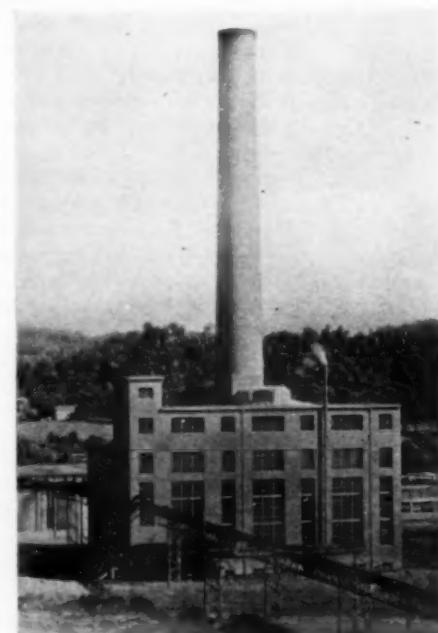
In undertaking the design of a power plant to serve a process industry, many factors must be considered, carefully weighted, evaluated, and assigned to their proper relative positions in the

general scheme. Firstly, it is imperative that the number or varieties of services be established and the yearly quantity of each determined. Probably the average hourly quantities will not be constant, but subject to variation, hence maxima per unit of time must be set up as a guide in selecting the capacities of the equipment.

Nearly all process industries require steam power, primarily used in various phases of manufacturing. Electrical energy is needed to run conveying and processing equipment and for illumination. Compressed air may be used for agitating and cleaning. Refrigeration facilities provide the cooling effect necessary in some processes. Any or all of these services may be provided by plant facilities as a concomitant part of the establishment; or they may be purchased in whole or in part. The two first mentioned are in general the most important, the largest in dollar value, and closely related one to the other.

The electrical industry, aided by science and engineering, is responsible for a development that offers to process industries a boon in the way of cheaper power services to supply high-pressure steam, and equipment that will generate and handle it. In the past five years or so, steam at pressures of 1,000 lb. and more has evolved into a practical, commercial reality. It offers almost unlimited possibilities to industrial plants generating part or all of their electrical energy, as this energy may be developed as a byproduct.

Establishment of one or more pressures for process purposes, by one familiar with the requirements, should be at as low pressures as the processes and rapidity of production permit. It is then possible to approximate a working pressure for the boiler and turbine units. Knowing the steam available for energy generation, the designer is able to compute the latter and compare it with the requirements. If it be insufficient, then the boiler pressure must be increased until the electrical energy made available by expansion of the steam within the established limits exactly



balances that needed. Generally it is not necessary to exceed 600 lb. pressure to develop all the electricity desired, although up to 1,400 lb. is available if needed.

If it be assumed that the majority of industrial processes require steam at about 125 lb. pressure or less, it is probable that high-pressure steam will be most valuable as a producer of byproduct energy rather than directly in process applications. For example, if the 125-lb. steam requirements were generated at about 200 lb. pressure, as is often the case in many existing establishments, but little electrical energy would be developed by passing it through a turbine at the latter pressure and exhausting at the lower pressure. If, on the other hand, the steam were developed at slightly under 500 lb., so as to avoid more expensive boiler construction, and exhausted from the turbine at 125 lb., the amount of energy obtained from the same quantity of steam would be increased over 200 per cent at an added fuel cost of less than 5 per cent.

A turbine engine is essentially a means of reducing pressure under conditions of continuous steam flow. It may be designed to operate under any initial pressure and temperature conditions up to the maximum of 1,350 lb.; to pass any reasonable quantity of steam

through the throttle; to expand the steam down to predetermined intermediate pressures; to expel a portion of the initial quantity and continue the expansion of the balance to the exhaust pressure; and to generate a definite quantity of electricity during the process of expansion. The energy so produced is a byproduct of the steam, for the latter is still available for process purposes at pressures less than the initial. The process of extraction may be reversed and steam from another source, at a pressure less than that of the throttle, may be introduced into the proper stage of the turbine and expanded to a lower pressure, meanwhile generating energy. Such a machine is a mixed-pressure turbine.

It is not difficult to prove the economy of byproduct energy generation. If the boilers, turbines, and generators were perfect mechanical devices operating at 100 per cent efficiency, it would be necessary only to fire a quantity of fuel containing 3,412 B.t.u. to develop 1 kw.-hr. However, none of the equipment is perfect; modern boiler units operate at efficiencies of 80-85 per cent, the latter figure not being unusual; turbines at 95-98 per cent; and generators at 90-96 per cent. Hence, a kilowatt-hour of byproduct energy may be had at the rate of a fuel expenditure equivalent to 4,300-5,000 B.t.u. per kilowatt-hour or 0.3-0.4 lb. of average coal. This follows from the fact that the electrical energy so produced need be charged only for the heat actually used in passing through the turbine.

On the other hand, a central station cannot charge the greater part of its fuel cost to process steam. It may be operating at 1,400 lb. and employing both the regenerative and reheat cycles; and yet it must be maintained at a high operating efficiency to show an economy of about 12,000 B.t.u. per net kilowatt-

hour. Many stations feel a very good showing is made if their rate is around 15,000 B.t.u., while there are older stations in service requiring up to 20,000 B.t.u. Developing electrical energy as a byproduct of the service of supplying process steam is analogous to removing part of the cream from the milk. The spread between initial and final steam pressures determines the amount of electricity that may be obtained from 1,000 lb. of steam. The fuel cost for power is only that increment required to furnish the equivalent of the heat transformed into electricity. Many industries contemplating a step toward increased boiler pressure can obtain the advantages of so doing by reducing their process-pressure requirements and so retain the present boiler pressure. This is, in effect, a reduction of back-pressure with the advantage of lower-price boilers.

Probably it is desirable to modify in a measure the broad statement advising balancing the total electrical generation against the maximum demand. It may be that at certain times, or when some of the processes deviate from their proper cycles, there is a disproportion of electrical energy to steam power demand, wherein the former exceeds, resulting in a peak demand for energy over a short period. It is not economically sound to raise the boiler pressure to provide for this small block of peak power. Rather it should generally be purchased, particularly if some standby service is normally contracted for from the local public utility because spare equipment has been curtailed. If a new plant is in effect an extension to an existing one which formerly operated condensing turbines, the peak load may be carried on these units.

Not infrequently the manufacturing plant's demand for steam fluctuates widely over a brief period. The invest-

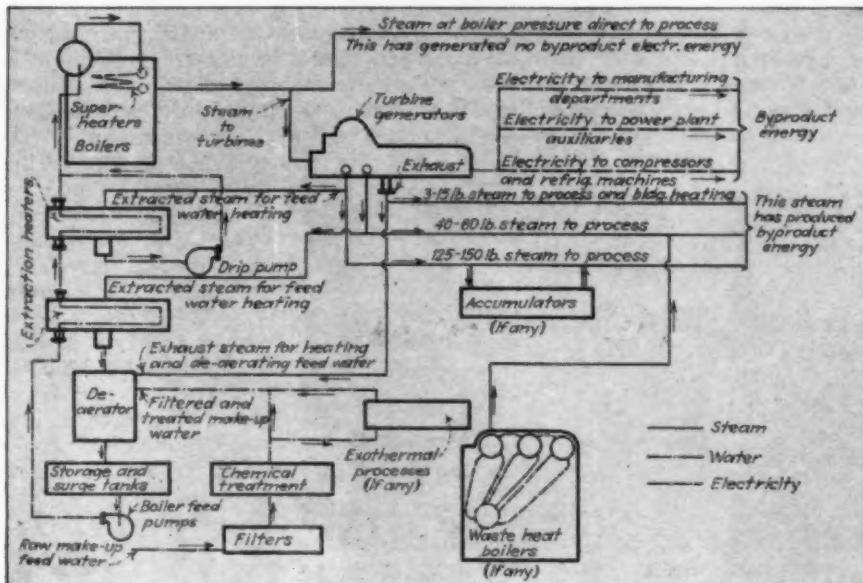
ment in boiler capacity to provide for such sudden demands is seldom warranted. Recent practice suggests the use, in such cases, of steam accumulators to cushion the shocks otherwise transmitted to the boilers themselves, with generally consequent derangement of their working pressure. That operating pressure should be selected for the accumulators which will permit them to discharge directly to the process that causes the disturbance by irregular demands. The present practical pressure limit for accumulators is 200 lb. It should not be inferred that they are equipment capable of giving something for nothing by a feat of legerdemain, for it is necessary to charge them with potential power at off-peak periods, when there is capacity available for so doing. Like the flywheel of an engine, they absorb power and store it against delivery at some future time when it is needed more than at the periods of low load.

Some processes furnish vast quantities of waste gases at elevated temperatures. Provided the gases do not react chemically with iron and steel, and depending largely on their temperature, they may be utilized in waste-heat boilers, whereby some of the heat otherwise lost will be retained. The operating pressure of such boilers usually should fit into the general scheme of pressures, so they may supply steam directly to some other process, in conjunction with steam that has passed through the turbines. There are occasions, however, where it may be preferable to generate waste-heat steam at the same pressure as the main boilers, using it as an addition to the main high-pressure supply.

Direct application of high-pressure steam affords some advantages where the temperature desired does not exceed about 600 deg. F. The applications will be limited probably to those where the available latent heat in the steam suffices for heating purposes, as saturated steam is an excellent vehicle for heat and is more susceptible to close temperature control than is electricity. Control of the steam pressure at any predetermined point establishes a corresponding constant temperature regardless of changes in the rate of heat absorption.

It should not be inferred that the use of high steam pressures is promiscuously advocated as a broad general policy for the process industries. Rather one should use the optimum initial pressure warranted by a particular situation. Production costs must be determined upon no less a basis than the annual expense of producing the services demanded. The total cost is made up of the operating items of fuel, labor, supervision, lubricants, supplies, and miscellaneous allied expenses; maintenance expense, including maintenance material, labor, and supervision; and fixed charges, consisting of depreciation, interest on the investment, taxes and insurance on the power plant; and any

Diagrammatic Arrangement of Power Services Supply Showing Byproduct Energy Generation



portion of the establishment's overhead allocated to supply of services. Basing conclusions and subsequent recommendations upon unit costs of services is likely to be misleading.

The possibilities of generated energy have been discussed quite thoroughly and the limits within which its generation at the works is feasible have been generally outlined. In some instances, although it is economically desirable to make all the steam, this will not be true in the case of the electrical energy. Purchase of part of the requirements may be advisable. Contracts for a supply usually are on the basis of a yearly energy consumption within certain maximum hourly demands. Such demands should be minimized and complete use made of minimum contract consumption. Just how much should be purchased can be determined only by setting up certain assumed combinations of quantities of generated and purchased energy and selecting the least expensive. To the annual production costs of the generated portion, determined as previously outlined, must be added the power company's billings for the purchased part. Again, conclusions must be based on the total cost for a period of not less than a year.

Distribution of steam and electric services is frequently a problem of major proportions. Overhead pipe lines and cable runs probably are the cheapest method where distances are in the order of 1,000 ft. or more, but they are permissible only when the industrial site is not badly congested. Whether pipe lines conveying steam and water services are carried above or below ground, they must be designed to minimize thermal expansion strains, facilitate draining, and be substantially supported and anchored. Above the ground surface, they may be carried on wooden poles or steel tower structures, and below, in covered concrete trenches or tunnels protected against flooding and from damage overhead. Steam lines must be insulated to reduce condensation and water lines, if they are outdoors, against freezing.

Electrical energy can be distributed overhead by triple-braid, weatherproof, covered conductors carried on standard insulators. If underground, then lead-covered conductors are used in fiber conduits buried in a concrete envelope. In no case should electrical feeders be carried in a tunnel with steam and water lines. Distribution of energy over a distance of 1,000 ft. or more is preferably at the generator voltage, and 2,300 volts, a.c., has proved quite satisfactory for industrial purposes. On large projects, energy at this voltage is

transmitted to small local indoor substations for further distribution. Some of the energy, after passing through the local switching structure, goes directly to 2,300-volt motors, and the balance is stepped down through transformers to 440 volts for the smaller motors. For short distances from the point of generation, supply may be sent out at 440 volts. The higher voltage requires the use of oil circuit breakers at all points, while the lower voltage permits using safety switches in the power house and safety switch cabinets in the manufacturing buildings. Where fire pumps are motor-driven, they must be served over two independent circuits carried in underground runs directly from the power house.

Compressed-air service may be provided by one of two methods. Probably motor-driven units are the better choice, using synchronous motors and short rope or belt drives. This type of motor offers some power-factor correction, especially desirable in the smaller industrial plants where the quantity of auxiliary electrical power is an appreciable part of the total generator capacity. Steam-driven units can be used advantageously if there is a demand for the exhaust steam; usually for heating the boiler feed water. However, due to contamination with lubricants, the oil and grease must be extracted before such steam can enter the plant system; otherwise, disastrous results may develop in burnt-out boiler and furnace water-wall tubes. If it is determined economically desirable to use steam drive, then the initial steam pressure should correspond with one of the process pressures, probably 125 to 135 lb., the supply being obtained from one of the extraction points on the turbines or from their exhaust.

Similar logic should be used in selecting the method of driving the refrigerating service equipment. Synchronous motors offer a particularly advantageous arrangement, as their application to this service gives better power-factor correction, because the load is more uniform than in the case of air compressors that are unloading frequently. The power-factor-correcting capacity of this type of motor leads to lower monthly billings, if part or all of the electrical energy is

**Table I—Spread of High Pressures
In Industrial Power Plants**

	Boiler Pressure, Lb.				Totals
	300 to 400 to 600 to 1,200 to 1,800	400	600	1,000	
Paper.....	15	21	3	—	39
Metal working	15	12	2	2	31
Textile.....	7	9	—	—	16
Chemical.....	8	6	1	—	15
Oil.....	1	3	—	—	4
Sugar.....	3	1	—	—	4
Rubber.....	—	3	—	—	3
Lumber.....	1	1	—	1	3
Salt.....	1	1	—	—	2
Miscellaneous.....	17	8	—	1	26
Total.....	68	65	6	4	143

purchased, and such a type should be used wherever possible on those circuits supplied by a public utility.

Process industries in general return but little condensate to the power house, so the percentage of make-up water required to replenish the system often amounts to 80 per cent of the total. The raw water available is frequently contaminated and unfit for boiler purposes, especially when steam generation is at high rates of evaporation. The method of feed treatment and chemical control must be given careful consideration; otherwise, scale will cause operating troubles which are aggravated by high-pressure operation. Complete de-aeration of the boiler feed is desirable to avoid corrosion and pitting of boiler, furnace, and economizer parts. An opportunity exists in the case of some chemical processes that are exothermal to pick up heat at some point in the feed-water cycle and effect a little economy. Whether or not this may be worth while can be judged by balancing the value of the heat obtained, in terms of the cost of equivalent fuel, against the fixed charges on the investment in equipment required to effect the capture.

A minor but none the less important item in the supply of power services is that of metering. Instruments of the recording type for this purpose are a worth-while investment which aids in allocating equitably service costs for accounting purposes and in detecting losses from the distribution system. The total send-out of each service from its point of origin, as well as the portion used by each department, building, process, or section of the manufacturing establishment, should be metered. The sum of the individual uses of each service should be balanced daily against the total generated, and any discrepancy must be corrected promptly.

Thus losses may be found, increases of consumption by any of the manufacturing divisions noted and explained, and controversies with division heads over service charges backed up with the documentary evidence of actual consumption.

As an indication of the trend in process industries toward high steam pressures and byproduct energy generation,

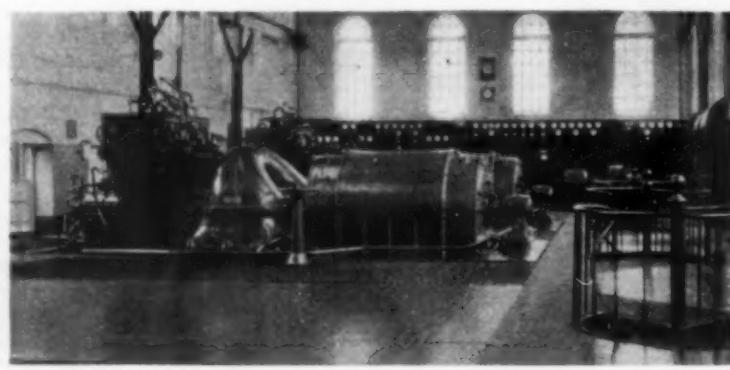


Table I gives a brief summary of the more important industrial power plants built in the United States and Canada during the last decade. The majority of the plants have been designed in the past five years and the tabulation is a fairly comprehensive survey of the high-pressure industrial field. There are some special cases not included in this survey where the demand for process steam has been so great in proportion to the electrical requirements that it has been jointly profitable for a public utility to build a central station especially to serve a process industry. The details of the better known instances are listed in Table II. Another interesting case is that of the New York Power & Light Corporation, which, in conjunction with the General Electric Company, will build at Schenectady, N. Y., a plant

Owner	Steam Pressure, Lb.			User
	Generates at	Delivers at		
Iowa Railway & Light Co.	225	100 & 5-25	Quaker Oats Co.	
Rochester Gas & Elec. Co.	320	150 & 15	Various Manufacturers	
Consol. Gas, El. Lt. & Pr. Co. of Baltimore.	375	100 & 15	Western Elec. Co.	
Southeastern Production Co.	450	150, 35 & 5	International Paper Co.	
Louisiana Steam Products, Inc.	640	135	Standard Oil Co. of Louisiana	
Deepwater Light & Power Co.	1,400	180	E.I. du Pont de Nemours & Co.	

using mercury vapor equipment to supply the latter company with process, testing, and heating steam, the byproduct energy in excess of that required by General Electric being sent out over the power corporation's power lines.

DESIGNING EQUIPMENT FOR HIGH PRESSURES

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◆ THE IMPORTANCE OF PRESSURE as a variable in carrying out chemical reactions on an industrial scale is becoming increasingly evident. The use of moderate pressures in chemical industry is not new, but the use of pressures above approximately 50 atmospheres (750 lb. per square inch), which will be arbitrarily defined as the lower limit of the high-pressure range, is a comparatively recent development. A summary of the chief accomplishments in this field to date would include the direct synthesis of ammonia by a number of processes utilizing pressures from 100 to 1,000 atmospheres, the synthetic production of methanol and more recently of higher alcohols, the synthesis of urea from carbon dioxide and ammonia, the hydrolysis of chlorbenzol to phenol, the production of anilin from chlorbenzol and ammonia, the hydrogenation of coal and oils, and some of the cracking processes used in the petroleum industry. A more comprehensive review of high-pressure developments recently appeared in *Chem. & Met.* (vol. 37, p. 530, N. W. Kruse). In the space allotted to this paper, it is possible only to outline some of the main problems that arise in high-pressure design and to suggest some methods of attack. References to papers previously published, where further details on particular points may be obtained, will be given.

Mechanical factors in high-pressure

design have been extensively discussed in recent issues of *Chem. & Met.*, but a general survey seems desirable. Practically the only metals that come into consideration for the pressure-sustaining shell of high-pressure vessels are steels, either the ordinary low carbon or alloy steels containing small quantities of nickel, chromium, vanadium, and the like. Certain ferrous alloys high in nickel and chromium have limited application, notably for the catalyst tube in the Claude process of ammonia synthesis, which operates at 900-1,000 atmospheres. For vessels to be constructed of steel plate rolled into cylinders and welded, such as cracking stills, low carbon steels are used. Shells of converters used in the higher-pressure processes, such as ammonia and methanol syntheses, are commonly constructed of a chrome-vanadium steel (1.0-2.5 per cent Cr, 0.2 per cent V, 0.3 per cent C), not only because of its excellent tensile properties but also because of its ease of casting and forging, and its uniform quality.

The usual method of determining the proper dimensions for safe design of cylindrical vessels is based on the equation

$$t = \frac{f p D}{2 T}$$

where t = wall thickness in inches, D = internal diameter in inches, p is the working pressure in pounds per square inch, f is a factor of safety, and T is a tensile property of the metal expressed in pounds per square inch.

In place of $\frac{T}{f}$ one may write S , the

allowable stress in the metal. Sometimes a factor, e , representing the efficiency of welded joints is introduced, but it has been repeatedly demonstrated that with modern welding technique the efficiency of welded joints on large vessels is practically 100 per cent. The value of f to be used depends on what is chosen as the fundamental tensile property. The older and probably still the most common method is to use for T , the ultimate tensile strength based on the initial area of the test piece, and take $f = 5$. Another method is to use the yield point or the proportional limit with $f = 2.5-3$. The data commonly used are those measured by short-time tests at room temperature. When the vessel is to be used both at high pressure and at an elevated temperature, it becomes important to consider how steels behave under stress as the temperature increases. In general it may be stated that the behavior of both the carbon steels and the alloy steels is similar, in that there is no appreciable decrease in tensile strength or proportional limit below 500 deg. F., but above that a marked decrease occurs. Table I gives some comparative figures for three steels.

Very little work has been done as yet on the tensile properties of metals at elevated temperatures, but its importance for intelligent design will be readily appreciated from the above figures.

The use of the proportional limit at the service temperature in the above formula will give a safe design, but an uneconomical one, and it is also open to the objection that the proportional limit is difficult to determine at elevated temperatures. Above the true proportional limit at elevated temperatures, steels show a continual, slight elongation, or "creep," under the action of a sustained stress. A definite tensile property, known as "creep stress," or "creep limit," may be defined as that stress which, when maintained constant, will produce no more than a certain elongation in a certain long period of time (usually 1,000 hours or more). The percentage elongation and the time are arbitrary and can be varied to suit the particular case for which the data

Table I—Behavior of Steels at High and Low Temperatures†

Steel	Tensile* Strength at 70 Deg. F.	Tensile* Strength at 1022 Deg. F.	Proportional Limit at 70 Deg. F.	Proportional Limit at 1022 Deg. F.
0.38% carbon	84,200	40,000	32,700	7,750
3.5% Ni, 0.37% C	104,300	35,400	51,900	8,250
1.0% Cr, 0.2% V, 0.37% C	144,300	83,300	88,000	17,000

*Based on short-time tests. †From Bureau of Standards Technologic Paper No. 205; H. J. French.

are desired. The long-time ultimate strength obtained by plotting the ultimate strength versus time at constant temperature and taking the asymptotic value, is another property that is used. It has the advantage of being relatively simple to measure. For low carbon steels at 900 deg. F. it is only about one-half of the short-time ultimate strength. The use of some long-time tensile property with the proper safety factor appears to offer the most intelligent solution of the problem. For further details on these points, see the following papers: J. K. Wood, *Chem. & Met.*, Vol. 36, pp. 610-613, pp. 737-740; S. D. Kirkpatrick, *Chem. & Met.*, Vol. 36, pp. 526-527; N. W. Kruse, *Chem. & Met.*, Vol. 37, p. 540; J. A. Lee, *Chem. & Met.*, Vol. 37, p. 587; T. M. Jasper, *Ind. Eng. Chem.*, Vol. 20, p. 466; White & Clark, *Power*, Vol. 69, p. 898.

The simple design formula given above assumes a uniform circumferential stress in the cylinder walls. This is only true for relatively thin-walled cylinders. For thick-walled cylinders, the following formula, due to Clavarino, may be used (based on one-third for the Poisson ratio):

$$t = \frac{D}{2} \left[\sqrt{\frac{3S + P}{3S - 4P}} - 1 \right] = C \frac{D}{2}$$

Ernst, Reed, and Edwards (*Ind. Engr. Chem.*, Vol. 20, p. 466) have plotted values of C versus P for various values of S , and their curves offer a convenient solution of the Clavarino equation. The following table compares the allowable internal pressure as a function of the ratio of outside to inside diameter for an allowable stress of 15,000 lb. per square inch, as obtained from the two equations:

O.D. T.D.	P (Simple Formula) Lb. per Sq.In.	P (Clavarino) Lb. per Sq.In.
1.05	750	855
1.20	3,000	2,930
1.50	7,500	5,630
2.00	15,000	7,950
3.00	30,000	9,740
5.00	60,000	10,700
∞	∞	11,250

Assuming the Clavarino formula to be approximately correct, this clearly shows that it should be used for ratios greater than 1.3, and it also shows that little is gained by using a ratio greater than 2.5 to 3. The thin-cylinder formula has been experimentally tested and found to be reasonably correct, but, to our knowledge, there has been no such check of the Clavarino equation.

There are two general classes of containers for high-pressure service, the one being made from steel plate with all welded seams and the other consisting of seamless vessels. It is possible to bend and to weld plate successfully up to about 4 in. thick, and large vessels of this type have been built. It is beyond the scope of this article to discuss methods of welding as applied to the fabrication of pressure vessels, but suffice it to say that numerous highly satisfactory techniques have been worked

out giving welds with tensile properties equal to that of the adjacent metal of the plate. In general it may be said that this type of vessel is used for pressures below 1,000 lb. per square inch. For the higher pressures, seamless vessels are more commonly used. These are of two general types, according to the method of fabrication.

Smaller seamless vessels having relatively thin walls, such as the cylinders used for transporting high-pressure gas, are made from plate by a cupping and drawing process. The larger, thick-walled vessels are made from a cast ingot which is pierced for a mandrel and then forged to shape on hydraulic presses. The largest cylinders of this type that can be made have an internal diameter of 6 ft. and the length is determined by the fact that the maximum weight of ingot that can be handled is about 225 tons. For further details on the fabrication of pressure vessels, the following references may be consulted: T. M. Jasper, *Ind. Eng. Chem.*, Vol. 20, p. 466; *Chem. & Met.*, Vol. 37, p. 565; F. O. Leitzell, *Chem. & Met.*, Vol. 37, p. 566; J. L. Cox, *Chem. & Met.*, Vol. 37, p. 585; R. S. McBride, *Chem. & Met.*, Vol. 35, p. 396; N. W. Kruse, *Chem. & Met.*, Vol. 35, p. 661.

One of the chief problems in the design of large welded pressure vessels, such as those used in the petroleum industry, is the proper shaping of the heads and the reinforcement of the necessary openings in the tank to prevent regions of stress intensification with resultant failure at pressures considerably below that at which the simple cylinder would fail. In other words, the vessel should be designed so that no part is weaker than any other, and, in theory, its failure should resemble that of the famous "one-hoss shay." This is too complex a problem for purely mathematical solution, but considerable progress has been made by the rather costly experimental method of testing large vessels to the point of failure and measuring the stress-strain relations at numerous points.

Space does not permit any treatment of the methods used for closure of the large forged pressure vessels, such as are used for catalyst chambers in ammonia or methanol syntheses, nor of such important items as high-pressure piping, valves, fittings for making connections of numerous sorts, design of gaskets, and the like. The following references are given for details on these and related matters: Ernst, Reed, and Edwards, *Ind. Eng. Chem.*, Vol. 17, p. 775; *Chem. & Met.*, Vol. 37, p. 577;

Dilley & Edwards, Circular 61, U. S. Dept. of Agriculture; Ernst and Reed, *Mech. Engr.*, Vol. 48, p. 595; F. A. Ernst, *Ind. Eng. Chem.*, Vol. 18, p. 664.

The compressor may be said to be the heart of any high-pressure gas-phase process, and much attention is now being devoted to improvements in compressor design to reduce power requirement, increase resistance to corrosive gases, obtain higher pressures, and insure better continuity of operation. See the following articles on this subject: *Chem. & Met.*, Vol. 37, p. 570; R. W. Miller, *Chem. & Met.*, Vol. 37, p. 571; H. A. Sommers, *Chem. & Met.*, Vol. 37, p. 574; *Chem. & Ind.*, Vol. 48, p. 591.

There are many factors of a more strictly chemical engineering nature which enter into high-pressure design problems. As examples one might cite the calculation of gas volumes at high pressures, flow of fluids and its application to the calculation of pressure drops and pipe sizes, heat transfer, and the design of high-pressure gas inter-changers, vapor pressure relationships and applications to condenser design, and various special considerations involved in catalyst-chamber design, such as removing and conserving the heat of reaction and cooling the shell with incoming cold gas. The remainder of this article will be devoted to a brief consideration of some of these factors with some references to literature where more detailed information is available.

Under ordinary low-pressure conditions, the simple, ideal gas laws are sufficiently accurate for all engineering calculations. At high pressures the deviations from the simple behavior predicted by the equation $PV = NRT$ may become great and consequently of importance in engineering calculations. An idea of the extent of error involved in the use of the simple equation is given by Table II.

Research on the P-V-T relationships of gases and their mixtures is now being actively pursued at a number of institutions, and the most recent data can be secured only by going to the original papers. Ernst, Reed, and Edwards (*Ind. Eng. Chem.*, Vol. 17, p. 775) discussed the application of such data to compressor design. For engineering calculations it is desirable to have the data in the form of tables or graphs suitable for ready use. The new high-pressure steam tables and diagrams are an example of data assembled in this way. Such complete data are not readily available for other fluids. The International Critical Tables contain abridged tables of data in the form of

Table II—Error Involved in Use of Equation $PV = NRT$

Gas	Pressure Atm.	Temp., Deg. C.	Actual Volume in Cu.Ft. per Lb. Mol	Ideal Volume in Cu.Ft. per Lb. Mol	Ratio of Actual to Ideal Volume
Nitrogen.....	200	0	1.860	1.795	1.036
Nitrogen.....	1,000	0	0.741	0.359	2.064
Hydrogen.....	200	0	2.036	1.795	1.134
Hydrogen.....	1,000	0	0.615	0.359	1.711
Carbon Dioxide.....	100	40	1.11	4.12	0.269
Steam.....	81.6	617.7	7.45	10.30	0.723

the PV products for numerous temperatures on a number of common fluids, and some excellent equations of state (F. G. Keys, Proc. Nat. Acad. Sci., Vol. 3, p. 323; *J. Am. Chem. Soc.*, Vol. 43, p. 1452; and J. A. Beattie and O. C. Bridgeman, Proc. Am. Acad. Arts and Sci., Vol. 63, p. 229) have been published which represent the experimental data quite accurately for many common gases. Such an equation contains a large quantity of data in a highly concentrated form, but one objection to most of them is that the volume is not given explicitly and must be calculated by a trial process. The simplest equation of state for actual gases (as distinct from ideal) is that of Van der Waal, and, while it is admittedly not very accurate from the point of view of the physical chemist, nevertheless it is sufficiently so for the great majority of high-pressure calculations. Its great advantage is its simplicity and the fact that it contains only two constants that are characteristic of the particular gas, and these constants are easily evaluated from the critical pressure and temperature.

Little experimental work has been done on the flow of fluids at high pressures or on heat transfer at high pressures, but on the basis of the well-established principle of the similarity of flow of all fluids, it is reasonable to assume that the present formulas, both for fluid flow and heat transfer, are satisfactory for gases at high pressure. It is well known that friction factors in the Fanning equation for fluid flow depend only

on the ratio $\left[\frac{du\varphi}{\mu} \right]$ where d is pipe

diameter, u is linear velocity of flow, φ is density, and μ is the coefficient of viscosity. In other words, the same equation fits the data on fluids varying enormously in density, and a gas at high pressure would fall well in between the limits to which the equations already apply. Similar considerations apply to the calculation of heat-transfer coefficients.

When one attempts to apply these equations, however, much of the fundamental data are lacking. For the case of fluid flow, viscosities and densities of gases at high pressure are needed. Methods of obtaining the density data have already been briefly touched upon, but data on the viscosity of compressed gases are almost completely lacking. Boyd (*Phys. Rev.*, Vol. 35, p. 1284) has recently measured viscosities of H_2 , N_2 , and one mixture, at a few temperatures and at pressures up to 175 atmospheres. He finds a much smaller pressure coefficient of viscosity than indicated by the meager data of previous investigators. If the flow is well in the turbulent region, the effect of viscosity on the pressure drop or size of pipe is small anyway, and for pressures up to 200 atmospheres one could not make a serious error by assuming viscosity independent of pressure.

In the case of heat transfer, the surface coefficient for fluids to solid walls depends on the ratios $\left[\frac{k}{d} \right]$ and $\left[\frac{C_p\mu}{k} \right]$ as well as on the one given above, where k is the thermal conductivity and C_p is the specific heat at constant pressure. The variation of C_p with pressure is fairly well known for a number of common gases (see International Critical Tables, and Mackey and Kruse, *Ind. Eng. Chem.*, Vol. 22, p. 1060). It may also be calculated from an equation of state or the equivalent data. The exact calculation is a laborious job, but the approximate calculation with sufficient accuracy for engineering purposes is comparatively simple.

There are no data, as far as I am aware, on the thermal conductivity of compressed gases. The kinetic theory as applied to ideal gases shows that both viscosity and thermal conductivity are independent of pressure. On the basis of this, one may assume that these properties are independent of pressure as long as deviations from the ideal gas laws are not great. Further progress in design of high-pressure heat-transfer equipment is largely dependent on the securing of further knowledge of these fundamental properties of compressed gases, supplemented by some actual measurements of heat-transfer coefficients for gases flowing under pressure.

When the design problem involves the removal of a condensable vapor from non-condensable gas, as in the recovery of anhydrous ammonia from the circu-

lation gases in the direct synthesis of ammonia or the reverse problem of saturating a gas with the vapor of a liquid, the question of deviations from the ideal gas laws again appears in an interesting form. Larson and Black (*J. Am. Chem. Soc.*, Vol. 47, p. 1015), working at the Fixed Nitrogen Laboratory, found that the concentration of ammonia in a compressed mixture of nitrogen and hydrogen in equilibrium with liquid ammonia was much greater than that calculated by the usual method involving the assumption of ideal gases and the assumption that the vapor pressure of liquids is independent of the total pressure. Even at 50 atmospheres the difference was considerable, and in one case, at 1,000 atmospheres, the actual concentration was six times the calculated one. Bartlett (*J. Am. Chem. Soc.*, Vol. 49, p. 65) has observed similar deviations in the case of water vapor in compressed gases, and some unpublished results from this laboratory indicate large deviations in the case of methanol. The importance of such data in the design of high-pressure condensing and gas-scrubbing equipment is obvious.

It has been possible to touch on only a few of the "high spots" in this review of high-pressure design. It is clearly evident, however, that much more fundamental work must be done on the properties of materials at high pressures and at elevated temperatures before the design of equipment to withstand such severe conditions and to operate economically can be said to rest on a sound, scientific basis.

PRESSURE VESSEL DESIGNER MUST MEET NEW NEEDS

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◆ ALTHOUGH THE DEMANDS of the chemical engineer are continually more exacting as to size of units and severity of service conditions, the equipment manufacturer has been successful generally in meeting these demands. Nowhere is this more plainly and interestingly marked than in the design and manufacture of pressure vessels, where the commercial development of a chemical process frequently depends upon the ability of pressure-vessel manufacturers to develop their practice to meet the new requirements.

The more common pressure vessels which entered into chemical plant instal-

lations a few years ago—such as autoclaves, bubble towers, dephlegmators, precipitators, reaction chambers, reflux exchangers, and scrubber towers—have undergone progressive improvements in construction and design, although in general it may be said that the vessels as fabricated were satisfactory for the particular service of the era in which they were built. In the day of comparatively low pressure and temperature, for example, the riveted type of construction was adequate, although it sometimes left something to be desired in its ability to remain tight under conditions of alternating heating and cooling or from the standpoint of resistance to localized embrittlement and corrosion.

Very little engineering design entered into these earlier vessels. They usually were planned by resorting to routine drafting methods based on the experi-

ence of practical boiler makers. However, when large-size operations are undertaken it nearly always follows that important engineering problems are introduced, and so it was with pressure-vessel design. It became necessary to supplement the earlier empirical methods with rational design.

Considerable has been learned in recent years regarding the behavior of metals under severe operating conditions. Research has also disclosed the magnitude and distribution of stresses throughout the pressure-vessel structure. This knowledge has enabled the designer to calculate the vessel requirements for a given set of operating conditions so that it will be free from dangerously concentrated stresses and of uniform and accurately known strength throughout its numerous members. The pressure-vessel manufacturer, therefore, is enabled to proceed with confidence to the building of large-size vessels. As a rule greater economy results when it is possible to use one large vessel instead of several smaller ones. The equipment investment alone based on unit output of product is known to have been reduced in some cases as much as 60 per cent due to the larger size. Along with the refinements of design, safety has been enormously increased.

The designer has been aided by improvements in fabrication and manufacturing methods. Reference has been made to riveted vessels. This type of construction has its limitations, because the riveted joint is permeable by many fluids even at moderate pressures. In addition there is a definite limit to the plate thickness which it is practical to rivet. In order to overcome the deficiencies of riveted construction, the forge and hammer-welded vessel was developed, and for a considerable period this type of construction was standard for vessels where absolute freedom from leakage was imperative under fluctuating temperature and pressure conditions. Many of these vessels, having a range of wall thickness from $\frac{1}{2}$ in. to $2\frac{1}{4}$ in. are a part of present-day installations

and are giving satisfactory service. However, with the hammer-welding process, the manufacturer was restricted to plates having a maximum strength rating of 50,000 lb. per square inch. Moreover, there were practical difficulties in making a hammer weld in plate more than 2 in. thick. These limitations were not in accord with the ideas of the process developers who began to talk of pressures up to 5,000 lb. per square inch and temperatures above 1,000 deg. F. One answer to the demand for vessels to withstand these elevated pressures and temperatures has been the vessel forged from a solid ingot. However, the cost of this type of vessel is high, the provision of outlets and nozzles on forged vessels offers difficulties, and for general application this type of vessel does not fit into installations with the same flexibility as fabricated equipment.

Recent far-reaching advances in the electric fusion-welding process have helped the pressure-vessel manufacturer keep pace with the process developer. The joints produced by this modern method of fusion welding are such as to require no discount as to ductility, strength, or any of the other desirable qualities of the base metal itself.

This process opens a field for the construction of vessels which can be designed for exact and definite stresses and for practical uniformity of stress throughout the vessel. Nozzles and openings can be reinforced on a truly rational basis. The embodiment in these vessels of ellipsoidal heads—another important advance in pressure-vessel design—completes a unit in which there need be no dangerous concentration of stress under any specified service conditions.

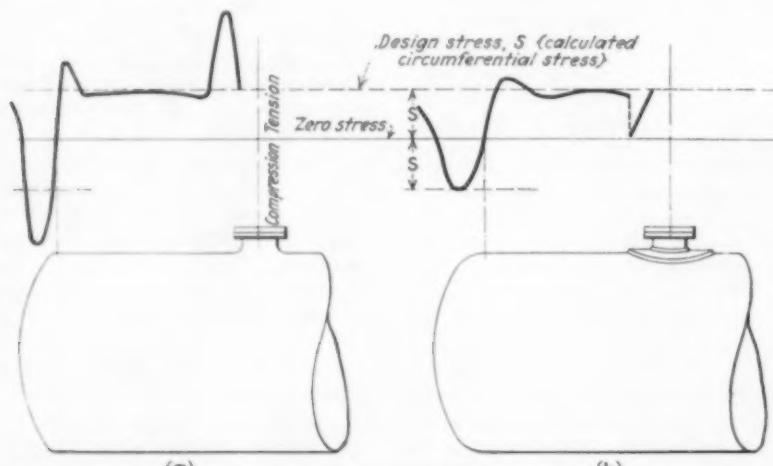
The sketch in the figure illustrates this point. The outline at (a) is of a vessel having a dished- or basket-type head and a plain flued nozzle characteristic of earlier practice. The vessel sketched at (b) has an ellipsoidal head and a reinforced built-up nozzle fabricated by fusion welding, typical of modern design. Just above the outline of

the vessels is plotted a curve showing typical variations in stresses measured in respective sections of such vessels when under pressure. The broken horizontal line in the graph represents the calculated circumferential stress in the cylindrical part of the vessels. The curves indicate wide variation and high concentration of stresses where the basket-type head and the flued nozzle join the shell, the maximum stresses at these points exceeding the hoop stress of the vessel. On the other hand, while there is some variation of stress throughout the parts of the vessel of modern design, the fluctuation of stress is much more moderate and the maximum stresses near the head and nozzle joints are practically the same as the stress in the shell of the vessel.

Recent advance in pressure-vessel construction has been the introduction of rolled seamless sections to replace flat plates rolled to shape. Seamless sections are fabricated into the vessel by electric-fusion welding and afford many advantages in chemical-process service. The method of manufacturing these seamless sections by rolling from acid open-hearth ingots produces a uniformity of analysis in the steel and a freedom from segregation which is never attained in steel plate. The strength of rolled seamless cylinders of carbon steel exceeds 60,000 lb. per square inch, and when rolled of alloy steels much higher tensile strength can be realized. The complete absence of longitudinal joints, attained by the introduction of rolled seamless cylinders, gives assurance that the metal is absolutely homogeneous along the lines subjected to greatest stress and affords a smoothness of interior surface. Tests of plate and seamless shell-steel samples in the same strong acid solution indicate that the latter corrodes less rapidly and more uniformly throughout its thickness than does high quality plate. The sizes of pressure vessels fabricated from these seamless cylinders are limited only by transportation facilities. Present practice is to limit diameters to 12 ft. maximum and thicknesses to 6 in.

When the processing of corrosive materials makes it desirable to line the vessel with alloys, fusion-welded construction is better adapted than any of the other methods. Liners can be built into a fusion-welded vessel so as to make a close fit and to form a perfect seal against contact with the fluid by those parts which it is desired to protect.

Improvement in design, the use of better fabricating processes, the availability of new alloys, and more extensive research data on the behavior of the carbon steels are the outstanding factors contributing to the present progress of pressure-vessel manufacture. It is realized that future developments in chemical processes will require equipment to withstand operating conditions even more severe than those encountered of today.



Comparison of Circumferential Stress Distribution in Vessel Having Basket Head and Plain Flued Nozzle With Vessel Having Ellipsoidal Head and Reinforced Fabricated Nozzle

TEACHING THE ROBOT TO THINK AHEAD

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◆ AUTOMATIC CONTROLLERS consist in general of two parts: a mechanism or instrument for detecting and measuring the magnitude of changes in the system under control, and a second mechanism for correcting these changes so as to maintain the system constant. A case of manual control will make this more readily apparent. The helmsman of a ship is standing at the wheel with his eye on the compass. Some cause external to the ship—a breeze or a current, perhaps—throws the boat slightly off its course, and he turns the wheel, bringing the ship back to its proper bearing. The compass is the detecting instrument, and the combination of

cause for variation in control. Changes in the system cannot immediately act through the controller to correct themselves any more than turning the rudder will immediately correct the ship's course. A helmsman who knows his business will anticipate changes, gage the rate of change, and act accordingly. This is the ideal toward which automatic control is tending.

Control is fairly simple in a reasonably stationary system; for example, in heating the contents of a kettle and attempting to maintain a constant temperature. However, let the material undergoing treatment be passing through the apparatus, as in any continuous process, and its control is immediately complicated tenfold. An example is a continuous water heater. Here we have to deal with two variables: the rate of flow and the temperature of the feed water. If one factor is constant and the time required for the temperature changes to adjust the flow of heating medium is small, control will be reasonably easy and accurate. But with the usual types of controller, one of two inaccuracies will be present. Either the temperature will go periodically above and below the control point with an "over-and-under" type of controller, as in Fig. 1, yielding a correct average but an instantaneous value that is correct only twice during the cycle; or with what may be called throttling control, the mechanism will produce a temperature that is constant, but slightly incorrect for all but one possible state of the input conditions. This may be visualized with the assistance of Fig. 2.

If it were possible for the correcting mechanism of an automatic controller to follow the detecting mechanism instantly and make the necessary changes instantly, then automatic control would be a far simpler thing than it actually is. Suppose the helmsman were always to wait until the compass showed the ship to be 5 deg. off course before turning his wheel, and suppose, further, that he held his rudder over until the compass again indicated the true direction. The result obviously would be a very crooked wake, for the ship would swing after the rudder had been returned to neutral.

This is exactly what happens with the average automatic controller. Instead of the physical inertia of the ship, and the mental inertia of the helmsman however, we find *lag* to be the usual

of Fig. 1. Here the stock, consisting of paper pulp and water, is flowing through a launder continuously at an assumed substantially constant rate. Its reaction against the control ball, which will just float in the stock, is substantially proportional to the water content (consistency) of the pulp. A motor-driven valve adds water to dilute the stock and this water is thoroughly mixed with the pulp before the stock reaches the control unit (ball).

Now assume that the valve opening is just sufficient to add the desired quantity of water and that the input stock is of constant consistency. In this case, the reaction against the ball is sufficient to hold it at an intermediate position between the "more" and "less" contacts, and the valve opening remains unchanged. Suppose, however, that the consistency of the feed suddenly increases, requiring a greater valve opening. The ball is forced to the left, closing the "more" contact and thus increasing the valve opening. If it were possible now for the valve to follow the change instantly, then the correct dilution would be possible despite the change, and there would be no problem. However, an appreciable time, *t*, must elapse for the diluted stock to flow from the valve to the controller. The limiting

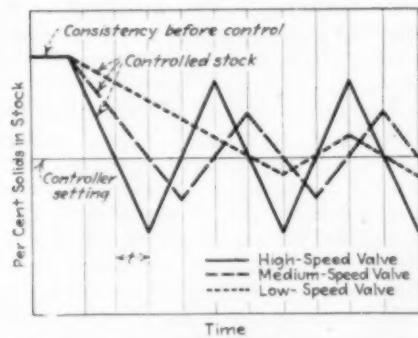


Fig. 1—Curve of Typical Over-and-Under Control

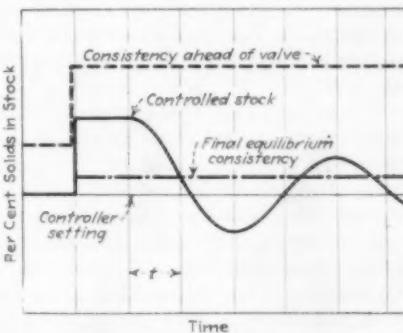


Fig. 2—Typical Curves Produced by a Throttling Controller

factor is the time required to secure thorough mixing. Consequently, the valve continues to open until the stock of the proper dilution has reached the ball, at which time too much is being added. Then as this too dilute pulp reaches the control unit, the ball moves toward the right, until the "less" contacts are closed and the valve opening begins to decrease. It is obvious then that the controller will constantly "hunt" for the proper valve setting without ever finding it.

All controllers of this type hunt continuously to a greater or lesser degree, giving an average that is correct but a varying instantaneous result. This over-and-under control may become so violent as to cause the valve to open and shut completely. In fact, some of the most common types of temperature controller operate on the fully open and fully shut principle. Such instruments are low in price and yet quite satisfactory for many cases. Where the lag is small, where

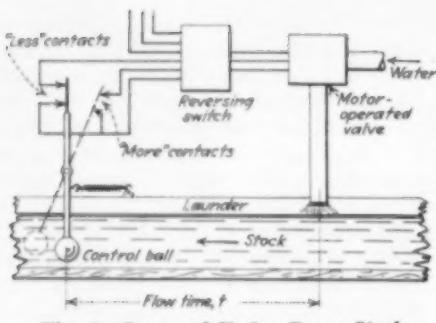


Fig. 3—Over-and-Under Paper-Stock Controller

very close control is unnecessary, or where it is possible to average the result by means of good agitation and large storage capacity, there usually is no reason why full on-and-off control cannot be used, provided that in certain cases the swings are reduced by means of a bypass of constant opening around the control valve.

It is in the other cases that more complicated instruments must be used. An improvement can readily be made to over-and-under controllers so that the control valve will "throttle" or assume a definite opening for every value of the variable. This consists in the addition of some form of mechanical or electrical "follow-up" device which will permit the swings of the controller to approach a constant value after any change, as in Fig. 2. The average fluid-operated temperature controller is of this type.

Returning to the same problem of paper-stock control, we find that the use of contacts attached to the rising valve stem, as in Fig. 4, will provide this sort of follow-up. When there is a large change in the stock consistency—an increase, for example—the control ball is forced forward, making a "more" contact which increases the valve opening. As the stem rises, however, the "more" contact tends to move away from the common contact. If it should move more rapidly or if the increase in density should be checked, the contact will be broken and the valve will remain temporarily at its new setting. Meanwhile, the pulp which has been diluted by the increased quantity of water is approaching the ball and as it arrives, the ball moves toward the right, very shortly making a "less" contact and closing the valve. As above, the follow-up will break the contact when the valve has attained a new setting; this time, however, on the low side. The control will continue swinging above and below the desired dilution, but slowly approaching a constant value.

If the range of acceptable moisture content of the stock be broad enough, and contacts consequently are far enough apart, this device will very shortly reach an equilibrium. On the other hand, for close control, which requires closely spaced contacts, it may hunt violently for a long time before settling down to the new conditions. It

should also be noted that this form of control will not give as an average result the desired value. Only under one concentration of incoming pulp will it give a product exactly as desired. Otherwise, the dilution will be slightly too great or too little, erring in the same direction as the incoming pulp, but to a lesser extent. This is explained by the fact that for every valve opening there must be a definite short range of positions of the ball in which contact will not be made in either direction—i.e., at equilibrium. Two different dilutions, therefore, will yield slightly different final results in bringing about an equilibrium. This condition is immensely aggravated if the detecting instrument itself is used to operate a balanced valve directly, instead of working through a true electrical or mechanical follow-up. It may be demonstrated mathematically that no ordinary follow-up can give exact control.

If the usual process of adding the dilution water before the controlling

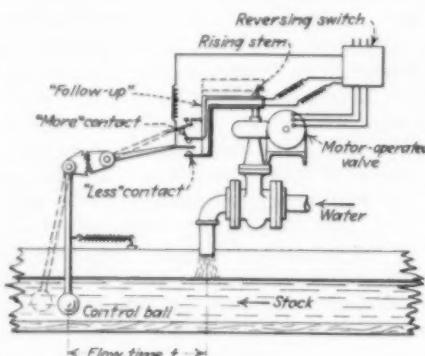


Fig. 4—Throttling or Follow-Up Controller for Paper Stock

unit could be reversed satisfactorily, a follow-up controller that would add the correct quantity of water under all conditions could be devised. In this case it would be necessary to maintain the flow of undiluted stock very accurately and to adjust the controller so that for each position of the ball, the valve would assume exactly the correct opening. The difficulties of such metering and adjustment are obvious. Also, since such an instrument would have no way of keeping a check on itself, dilution occurring after measurement, I doubt that it could be satisfactorily developed. I know of

no controller operating on this principle.

Whether a follow-up system will give better results than an ordinary over-and-under controller will depend largely on the circumstances. If properly designed, a follow-up or throttling controller will cease hunting after a short time but will give a slightly inaccurate result. An over-and-under controller will hunt continuously but give an average result that is accurate. For equal instrument sensitivity, assuming ample mixing capacity, the latter will always give greater uniformity than the former.

Elimination of most of the hunting, together with exactly correct control, is the next step. For most purposes, this can be accomplished by combining the principles of the throttling and the over-and-under controller so that the mechanism can come *slowly* back to the desired position, regardless of the valve opening. The device shown in Fig. 5 embodies the basic principles of a controller which was, so far as I know, first used many years ago in governing the hydraulic turbines at Niagara. In this controller, as in the others, the pull on the control ball *a* is substantially proportional to the percentage of dry pulp in the stock. Since the pull is balanced by a spring, *b*, the deflection of which is directly proportional to the load, then the movement of the ball is a straight-line function of the consistency. It might be used to operate a pen and draw a consistency curve on a drum or disk chart.

The exact method of obtaining the control is immaterial. The system shown is merely one possible application of the principle. A double-contact mercury switch, *c*, is mounted so that it will be horizontal when the control ball is in the position corresponding to the correct consistency. One end of the switch support moves up and down with the movements of the ball while the other is normally at a position dictated by the opposed compression springs, *d* and *e*, which are set for the desired consistency. When the consistency of the pulp increases, the ball swings to the left, tilting the mercury switch to the left and completing the "more" contact. This starts the valve motor, *f*, in the direction of increased opening and lowers a guided hydraulic dashpot or compensating cylinder, *g*, thus lowering

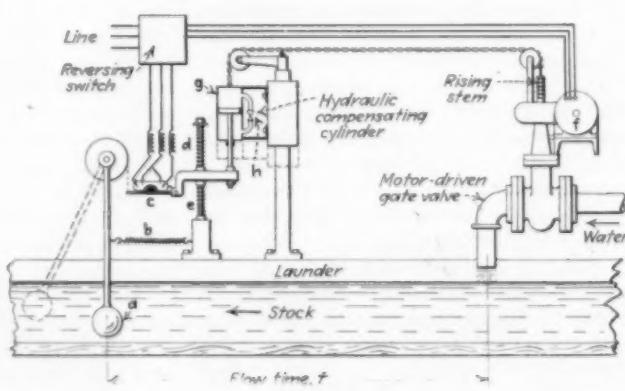


Fig. 5—"Niagara" Follow-Up Principle Applied to a Paper-Stock Controller

the right-hand end of the mercury switch against spring *e* and breaking the circuit. How rapidly the spring *e* will again raise the end of the switch depends on the adjustment of the bypass valve *h* in the hydraulic cylinder. Ordinarily this dashpot will be practically inoperative while the controller is oscillating to a new equilibrium. For all practical purposes, its action is almost identical with the simpler follow-up described above. When equilibrium has been attained, however, the difference becomes apparent. Whereas the other device established a slightly different equilibrium for each different entering consistency, the "Niagara" follow-up must eventually come to one definite equilibrium, whatever the entering pulp concentration. This is true because the springs, *d* and *e*, and the dashpot, *g*, operate together to vary the length of linkage between the valve and the switch and permit the latter always to return to the same point regardless of the valve opening.

One more step in automatic control is possible. A good helmsman gages the rate at which his turning of the wheel is righting the ship, and eases the wheel toward neutral *before* the proper course has been reached, thus allowing for inertia. In anti-aircraft and coast-defense practice we find an even closer analogy to the type of control we are seeking to accomplish. If

apply a negative correction shortly before reaching the control point to act as a brake and thus avoid overshooting. But to stop the control action exactly at the desired value, in the shortest possible time and without hunting, a rate-measuring and predicting controller is needed.

At each point on a curve of any process variable plotted against time, the slope of the tangent represents the rate of change at that point. Since the curve usually will approximate a straight line as it approaches the control axis, a knowledge of the slope can be used to establish a set-forward point very much as in artillery practice. It is necessary only to plot on a chart of the variable a right triangle which has for its base the lag, *t*, and for the hypotenuse, the slope of the curve. Then the altitude of the triangle will represent the magnitude of the set-forward point, or in other words, the value which, due to lag between the detecting and correcting mechanisms, will be registered at the detector when the desired value has been reached at the correcting mechanism. Hence, although the detector shows a value too high or too low, as the case may be, an instrument which can find the set-forward point will be able to stop the correcting mechanism at just the right instant.

To plot this triangle mechanically, as an automatic controller must do, requires a means of determining the slope automatically at all times. Of many possible methods, one of the simplest is to use a small wheel mounted like a caster which will trace over an imaginary curve of the variable, at all times aligned along the tangent. Then a pointer attached to the caster will represent the slope at each instant, and it can be used mechanically to complete the triangle and locate the set-forward point.

A schematic representation of this principle appears in Fig. 6. A caster, *a*, attached to a rod, *b*, moves vertically across a constant-speed moving belt, *c*, which takes the place of a chart. A contact point, *d*, is fixed above the control axis at a distance, *t*, from the projection of the caster center (*t* is the distance *c* moves in time *t*). Then as the caster and its pointer, *e*, move downward with decrease in the variable, and as the belt moves toward the left, a position will be reached, as shown by the dashed line, where the pointer will complete the triangle by making electrical con-

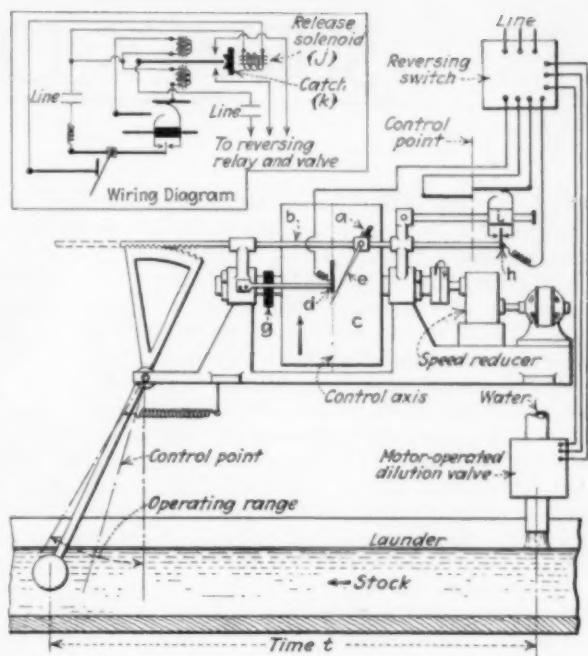


Fig. 7—Simplified Paper-Stock Controller Using Principle of Fig. 6

tact with *d*, which will stop the further change of the correcting mechanism at just the right value.

Extension of this system to a complete instrument is illustrated in Fig. 7, which makes no pretense to being a mechanically perfect design but merely suggests the lines along which such a design might proceed. Here again the problem is to control paper stock consistency. The control ball deflects directly in proportion to the consistency. Its displacement locates the caster *a* and the rod *b*. Instead of a belt in contact with the caster we are using a constant-speed drum, *c*. The set-forward contact *d* is mounted on a chopper bar which moves it outward at frequent intervals through the action of the cam *g*. The valve motor is controlled by the moving contact *h* and the sliding "more" and "less" contacts *i*. After any correction has been made and the caster is moving toward the control axis, the pointer *e* will finally arrive at a position where the set-forward contact will be made as *d* moves out to touch *e*, and immediately the release solenoid *j* and the catch *k* will act to stop the valve.

Various refinements could be made to this device without difficulty. Quicker control on very small changes could be had by obtaining an "inch" action of the valve in these cases through a fairly simple alteration of the chopper and contact mechanisms. Use of a dashpot would eliminate needless action during momentary fluctuations. Driving the drum from a propeller in the stock stream, or placing the detecting element in a constant-flow bypass, would eliminate the inaccuracies resulting from flow variation. Thus it seems evident that predicting controllers operating on some such principles as these should be possible for almost any variable.

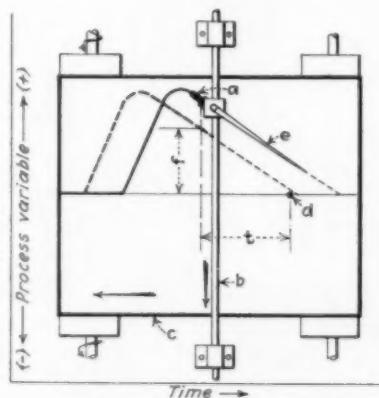


Fig. 6—Schematic Representation of a Simple Predicting Controller

the position of the target is plotted against time, it is then possible to determine where it will be when the projectile has arrived, and thus, through the use of a "set-forward point," to aim sufficiently ahead of the target to insure a hit.

A process controller to accomplish the same thing must be able to gage the rate of change of the variable and predict the point at which its value will be correct. Without actually predicting, certain control instruments now approximate this result very closely by making small periodic corrections and waiting after each to determine the effect. Some controllers are able to suit the magnitude of the correction to the amount of the change, and some

SURVEY OF DESIGN ADVANCES

◆ IN A BELIEF THAT DESIGN improvements in process equipment had been especially fruitful during the past three years, *Chem. & Met.* sought the assistance of equipment manufacturers in an effort to discover just how far these improvements had gone. To this end, questionnaires were addressed to a large number of manufacturers in the fields of chemical-engineering and allied equipment. This was done with the explanation that a concerted fact-finding effort at this time might assist materially in promoting the sort of thinking that leads to business recovery.

Results of the survey were very illuminating in some details, although not so conclusive in others. Because of the very broad territory that was to be included, phrasing of the questions was necessarily of a general nature and resulted in a lack of detail which makes exact conclusions impossible in some phases. In general, however, the findings are entirely satisfactory, in that they show the very active interest in the design which indicates the upturn in the business situation. That this interest is coincident with the commencement of business revival has been proved conclusively in earlier depressions.

Slightly less than 20 per cent of the manufacturers addressed replied, which may be considered a good showing. Of these a considerable number believed their developments to be of too little interest to merit a report. The remaining 137 replies are summarized and tabulated in the chart at the right. Replies from manufacturers of process apparatus total 110. The other 24 replies concern such collateral machinery as electrical and power equipment and auxiliaries.

The scheme used in drawing up the questionnaire will make the tabulation easier to interpret. The questions were put in the form of a check sheet somewhat similar in appearance to Table I. Types of equipment headed the columns, while the rows represented 27 different design improvements of a general nature, dealing with performance, fabrication, and mechanical features. Each manufacturer was asked to select his more important products from the equipment list and to put a check mark in the column for each of the several design improvements that had been effected in that particular piece of equipment during the last three years.

Tabulation has been carried out in a similar manner, except that the uppermost row lists the number of replies for each type of equipment. Below these, the figures show the number of manufacturers of each type who have made the improvement represented by each row. For example, of the four

manufacturers reporting on classifiers, two stated that redesign had accomplished longer life; four, higher efficiency; three, higher capacity; one, lighter construction; one, stronger construction; three, lower cost; and so on.

This process of following down a column on a particular piece of apparatus is frequently illuminating, but it does not give the indication of trends that may be gained from estimating the importance attaching to the various types of improvement. A method of gaging the relative importance of the improvements has been developed, and used to obtain the data of Table II. A summation of the numbers of makers reporting on each type, compared with the total number of individuals concerned, shows that the average number of pieces of apparatus reported by each of the 137 manufacturers is 2.5. Then the total of 341 products may be compared with the total of each row, giving as a result a series of "improvement coefficients." These are listed in decreasing order in Table II. It is obvious, of course, that there is nothing absolute about the coefficients, since not every improvement is applicable to each piece of equipment. However, they probably give a fairly ac-

Table I—Tabulation of Numbers of Makers Reporting Design Improvements in Process Equipment

Results of an investigation made by *Chem. & Met.* to determine the trends in

curate representation of the relative importance of the various design features in the field as a whole.

If we bear in mind the limitations of the improvement coefficients, it is possible to draw a number of instructive conclusions. In the first place, it is evident that longer life and higher efficiency have been the primary aims of the designer. In attaining these ends it is only natural that stronger construction and the use of corrosion-resistant materials should play a leading part, as they very evidently do from their position near the head of the table. In line with the increasing tendency toward concentration of production in

IN PROCESS PLANT EQUIPMENT

equipment design as shown by improvements effected during the last three years

larger plants, higher capacity is found in the next position. That lower costs should be a factor in only 32 per cent of the cases is somewhat surprising, in view of the general decrease in prices. It may be at the same time a good and a bad sign. On the one hand, manufacturers are evidently not producing a lower grade in an effort to attract business. On the other hand, evidence of a trend toward more economical design appears to be lacking in the majority of cases.

Greater ease of operation, next in interest, reflects industry's constant striving toward reduced labor cost and improved product. This is a rather in-

tangible improvement in its general application, and perhaps is not highly significant. Increased safety is much more important. It would naturally be expected to occupy a higher position than it does in the table. This, however, is one of the cases where the coefficient is a bad indicator, since an examination of those items which involve a hazard in operation will show that safety attains a coefficient close to 50 per cent when non-hazardous items are illuminated.

Welding appears to have gained ground in more than a quarter of the cases, a truly remarkable showing in view of its comparative newness. In those cases where its use is most logical, its progress is even more remarkable. It has been employed as an improvement during the three-year period by 100 per cent of the crystallizer manufacturers reporting, with percentages as follows in other cases: dryers, 75; condensers and heat exchangers, 73; evaporators, 69; tanks, 54; kettles, 50; stills and fractionating equipment, 46; filters, 45; towers, 43, and mixers, 40.

The observation that higher temperatures and higher pressures have not been given a more prominent place in recent design is explained by the fact that the greater part of chemical-engineering technology is still accomplished in the

Table II—Relative Frequency of Recent Design Improvements

	Improvement Co-efficient Per Cent
Longer life.....	57
Higher efficiency.....	57
Stronger construction.....	48
Corrosion-resisting alloys.....	38
Higher capacity.....	35
Lower cost.....	32
Ease of operation.....	28
Use of welding.....	27
Higher pressures.....	25
Increased safety.....	25
Standardization of the line.....	24
Higher temperature.....	23
Erosion-resisting alloys.....	22
Standardized parts.....	21
Anti-friction bearings.....	20
Ease of cleaning.....	20
Higher speed.....	19
Improved drive.....	18
Lighter construction.....	17
Designed for casting.....	15
Designed for riveting.....	12
Designed for forging.....	10
Automatic lubrication.....	7
Non-metallic materials.....	6
Designed for die casting.....	4
High-pressure lubrication.....	4
Use of new lubricants.....	3

range of moderate conditions. The spectacular nature of developments in several of the newer synthetic industries has perhaps tinged these characteristics with a generality they do not possess. An improvement coefficient of about 25 per cent, therefore, is more nearly within expectation than would at first appear.

Use of standardized parts and a standardized line of equipment makes an indefinitely low showing. One of the chief reasons for the enormous investment in plant required by most chemical industries is this very lack of standardization. As long as chemical operations are hedged about with secrecy, standardization will make but poor headway. There is no question but that lower equipment costs will follow on the heels of a more open-minded attitude on the part of chemical management.

With the exception of better equipment drives, the remaining coefficients allocate their respective improvements about as would be expected. With the advent of short-center belt drives and much more satisfactory equipment for driving direct, it would seem logical that the spread of improved drive should have been greater. That this evidently has not been the case constitutes an opportunity for the future which should not be overlooked.

As a whole, the survey indicates progress fully commensurate with the advances that have been made in other equipment fields. Fundamental engineering concepts evidently have gained in their application, and advantage has been taken of new materials and new fabrication methods. In general, the gains that resulted have included longer life, higher efficiency, and—although it is less frequently apparent—lower cost as well.

Equipment															Number of Makers Reporting								
Laboratory Apparatus	Magnetic and Electrostatic Separators	Materials Handling Equipment	Mixers and Agitators	Packing	Power Generation	Power and Process Steam Auxiliaries	Pumps, Pressure and Vacuum	Reaction Vessels and Autoclaves	Refractories	Refrigerating Equipment	Rolls	Scales and Other Weighing Equipment	Shipping Containers	Sieves and Screens	Steam Generation	Stills and Fractionating Equipment	Tanks and Vats	Testing Equipment	Thickeners	Towers	Valves, Pipe and Fittings	Other Process Equipment	
4	2	10	15	2	2	5	5	25	8	2	4	3	2	2	5	4	13	13	1	2	7	22	5
2	2	8	12	1	1	4	4	17	7	2	3	2	1	3	2	8	9	1	2	3	14	2	
3	2	8	13	1	1	4	4	16	3	1	3	2	1	1	3	2	7	1	1	2	5	9	
1	2	3	9	1	1	3	2	11	3	1	1	1	1	2	2	5	2	1	4	4	2		
2	2	2	2	4	4	6	2	1				4	5	3	1	2	3						
1	1	2	2	4	10	5	1					3	4	3		1	10						
1	1	2	8	1	3	9	2	1				1	1			1	1						
2	1	1	1	2	4	2	1					5	3			2	1						
2	2	7	9	1	4	2	10	5	1	2	1	1	1	4	2	6	9	1	4	9	3		
2	1	7	7	1	1	3	7	3	1	1	1	1	2	3	4	4	1	2	1	5			
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3	1	2	7	1	2	15	5	1	1	2	3	2	5	4	1	4	13	2					
2	2	2	2	1	3	1	12	2		2	1	1	2	3	2		2	11	2				
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3	6	1	1	1	2	2	2	2		1	6	7	1	3	8	2							
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1	3	2	1	2	1																		
2	3	8	1	1	8	2	1	1	1	1	1	4	5	1	1	1	3	3					
2	6	1	1	5	1						1	2	2	4		1	4	1					
2	10	2	1	2	4	3	1				1	1	2	4	6	1	9						

NEWS of the INDUSTRY



Students Course at Chemical Show

ANNOUNCEMENT is made that the students' course of lectures to be held in conjunction with the Exposition of Chemical Industries at Grand Central Palace, New York, May 4-9, will consist of three divisions. The first course will comprise a general survey of the field of chemical engineering, including a comparison of unit operations and processes, handling of materials, transfer of heat, materials of construction, typical unit operations, and a consideration of chemical engineering as a career.

Speakers will include: S. D. Kirkpatrick, editor of *Chem. & Met.*; W. S. Calcott, E. I. du Pont de Nemours & Company; W. H. McAdams, Massachusetts Institute of Technology; G. L. Montgomery, *Food Industries*; A. B. Newman, Cooper Union; F. C. Houghten, American Society of Heating and Ventilating Engineers; A. Anable, The Dorr Company; K. S. Valentine, Turbo Mixer Corporation; R. G. Walker, Oliver United Filters; and J. C. Olsen, American Institute of Chemical Engineers.

The second course, May 6-7, will include lectures covering the survey which must be made before an industry is established, what recent inventions have done for chemical industries, the relation of small-scale plant tests to large-scale development, and a thorough study of high-pressure technology and its place in chemical industry.

Speakers will be: F. J. Curtis, Merimac Chemical Company; W. J. Badger, University of Michigan; J. V. N. Dorr, The Dorr Company; C. P. Wood, Lockwood Greene Engineers, Inc.; J. R. Withrow, Ohio State University; N. W. Kruse, University of Illinois; B. F. Dodge, Yale University; P. J. Byrne, Hydro Engineering & Chemical Company; C. O. Brown, Nitrogen Engineering Corporation, and E. C. Bain, United States Steel Corporation.

The third course, May 8-9, will consist of a study of the career of the chemist and his work in the plant, in co-operation with chemical engineers, in consulting practice, and in the legal side of chemical industry, followed by lectures on the training of chemists in the university, in the plant, in industrial fellowships, and on the future of chemistry.

Lectures will be given by F. C. Whitmore, Pennsylvania State College; B. S.

Taylor, B. F. Goodrich Company; W. K. Lewis, Massachusetts Institute of Technology; W. M. Grosvenor, consultant; M. L. Crossley, Calco Chemical Company; N. E. Gordon, editor *Journal of Chemical Education*; H. W. Elley, E. I. du Pont de Nemours & Company; G. D. Beal, Mellon Institute, and H. E. Howe, editor, *Industrial & Engineering Chemistry*.

The dinner, which is one of the features of Chemical Show Week, will be held on the evening of May 7. Ira Vandewater, of R. W. Greef & Company, is chairman of the committee.

The professional group of Alpha Chi Sigma will hold a dinner at the Prince George Hotel on May 6. Dr. F. C. Whitmore will act as toastmaster and short talks will be given by Dr. H. E. Howe, L. V. Redman, Stroud Jordan, R. S. McBride, W. T. Read, and H. A. Curtis.

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Electrochemists Plan Interesting Meeting

THE fifty-ninth meeting of the Electrochemical Society will be held at the Hotel Tutwiler, Birmingham, Ala., April 23-25. The opening session will be devoted to a symposium on "Electrochemistry and Ceramics," with Prof. T. N. McVay, of the University of Alabama, as chairman. At luncheon there will be a round-table discussion on "Hydrogenation," led by Dr. W. D. Richardson, of Swift & Company. During the afternoon visits will be made to industrial plants.

On April 24, the morning session will be given over to a discussion of "Electronics," with Prof. Herman Schlundt, of the University of Missouri, presiding. Industrial plants will be visited in the afternoon. On April 25, Prof. A. Kenneth Graham, of the University of Pennsylvania, will conduct a meeting on "Electrometallurgy."

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Sulphuric-Acid Units Installed in Canada

INSTALLATION took place recently at Tadanac, B. C., of the first of three big sulphuric-acid units used in connection with fertilizer developments of the Consolidated Mining Company of Trail. Acid is being pumped to Warfield over a 6,000-ft. pipe to the plant. Each of the three units when installed will have a capacity of 113 tons daily.

Large Attendance at A.C.S. Meeting

INDIANAPOLIS' proximity to the geographical center of population of the United States doubtless contributed to the attendance of one of the largest meetings ever held by the American Chemical Society. More than 1,700 members and guests registered for the sessions, held March 30 to April 3. At the business meeting of the council, the society adopted a resolution introduced by Walter A. Schmidt, of Los Angeles, strongly condemning the increasing practice of certain chemists who lend their names and that of the society to testimonial advertising which imposes on the public's confidence in the chemical profession. A committee, headed by Dr. L. V. Redman, president-elect, was appointed to administer the prize of \$1,000 which D. A. C. Langmuir has contributed as an annual award for some deserving young chemist engaged in research. Approximately 425 technical papers were presented at the 50 divisional and sectional meetings. One that attracted much attention was a demonstration before the Petroleum Division of a new lubricating oil synthesized in the laboratories of the Standard Oil Company of Indiana, by polymerizing with aluminum chloride the olefines obtained by cracking paraffin wax.

An unusual feature of the meeting was the dedication at Bloomington on April 2 of the new Indiana University Chemistry Building. At that time it was announced that the eighty-second meeting of the society would be held in Buffalo during the week of Aug. 31.

Paper Interests Form Kraft Institute

LEADING producers of Kraft paper and kindred products have formed a Kraft Institute. The newly formed association comprises about 90 per cent of the manufacturing companies in that industry. The president of the institute is R. J. Cullen, of the Southern Kraft Corporation and the Continental Paper and Bag Corporation. Other officers and directors are D. C. Everest, vice-president and chairman; O. M. Porter, secretary, and Hugh Wright, treasurer. Members of the board of directors are: R. J. Cullen, D. C. Everest, Alfred Bleyer, H. L. Brown and F. M. Dickinson.

NEWS FROM WASHINGTON

By Paul Wooton

Washington Correspondent of Chem. & Met.

THE Manufacturing Chemists' Association of the United States is planning a broad program of expansion during the coming year. A technically trained assistant will be added to the Washington staff under the direction of Warren N. Watson, executive secretary, and the clerical force also will be increased for the purpose of expanding services rendered to the membership. Greater impetus also will be given to the work of the association's technical committees dealing with all types of chemical containers, the transportation of chemical products, and numerous other matters of common interest to manufacturers. Washington headquarters have been moved to a larger suite on the fifth floor of the Woodward Building. At the meeting of the executive committee on April 15 a new treasurer will be appointed to succeed the late Philip Schleussner, of the Roessler & Hasslacher Chemical Company, who died on March 23.

The Tariff Commission has assigned for hearing on May 26 the application of importers, made through Senate resolution by Senator Barkley, Kentucky Democrat, for a reduction in duties on glue and inedible gelatin. The glue industry has been under practically continuous investigation since 1924. The Commission made an investigation into glue and edible gelatin costs under the old tariff act and since 1930 revision has investigated edible gelatin, with the result that the duty has been cut below that carried by the 1922 act, sweeping away the increase granted in the 1930 act.

A TABULATION made by the Manufacturing Chemists' Association of the comparative exports of chemical products by the United States and Germany reveals a decline of 30 per cent in German exports of nitrogenous fertilizer materials. The decline from \$88,851,458 in 1929 to \$62,634,452 in 1930 is regarded as significant, inasmuch as fertilizers represent a large part of I. G. operations and an important source of its income and profits. German exports of all chemicals and allied products showed a decrease in 1930 of 13.6 per cent to \$292,577,248, as against a decrease in American exports of 15.8 per cent to \$127,985,736.

Shippers of alcohols and solvents are much disappointed by the Interstate Commerce Commission's delay in authorizing the use of the 5E drum, single-trip container. No opposition to the use of the "one-time shipper" developed at the hearing in February and shippers are anxious to dispense with the old returnable drums, because of the difficulty, delay, and expense that their use entails.

Nominally effective from April 1, the new industrial alcohol regulations issued jointly by the Department of Justice and the Bureau of Industrial Alcohol will not apply until received by permittees.

The life of present basic permits is not interrupted by the new regulations but becomes renewable Jan. 1 next and annually thereafter, in accordance with past practice. Applications for such permits will be subject in the future, however, to joint consideration by the Bureau of Prohibition in the Department of Justice and the Bureau of Industrial Alcohol in the Treasury Department. Outstanding withdrawal permits will remain in effect until July 1, and thereafter must be renewed every 90 days. Only one-third of the quantity authorized may be procured in any one calendar month. The fact that the withdrawal permits must not be approved by the Bureau of Prohibition removes the principal objection of the alcohol-using trades to the dual control system.

AS the new regulations reflect acceptance by the two government bureaus of practically every recommendation made by the industrial advisory council, they are expected to prove reasonably satisfactory to trade interests, with due regard to the fact that the Williamson Act, setting up dual control was opposed by the scientific and commercial organizations. Some provisions will impose an additional burden on consuming trades, but for the most part these were written into the law itself and could not be ignored in the regulations. It would be futile to deny that the new law and regulations signify a more strict government surveillance of the manufacture, denaturation, and use of industrial alcohol, but they have not been carried to the extent of destroying flexibility of commercial operations.

The regulations require considerably more paper work than in the past. Applicants for permits to manufacture any product, including ethyl acetatem lacquers, thinners, bay rum, etc., must submit evidence of the extent of business to be conducted. No permits for the use of specially denatured alcohol will be issued until processes and formulas have been approved by the Commissioner of Industrial Alcohol. Provision is made that liquid products must be unfit for use as beverages and that essential oils and chemicals will be of a proper character to effect that result. The regulations require filing of blueprints, plans, and specifications when required by the Commissioner, especially where denatured alcohol is to be used in a chemical process. Approval by the Commissioner of any process, formula, or preparation does not bind the

district supervisor to issue a permit, but provision is made for appeal.

Manufacturers using specially denatured alcohol are required to keep records of the purchase of oils, chemicals, and other ingredients used, together with original invoices. Inspection by officers or agents of either bureau has been extended beyond denatured alcohol and the products manufactured to the ingredients used in compounding such products. The sale of products such as bay rum, perfumes, toilet waters, hair tonics, etc., has been restricted to barber shops, beauty parlors, beauty and barber supply dealers, general retail stores, wholesale and retail drug stores, and ultimate consumers, unless otherwise authorized by the supervisor. The provision regarding commercial labels has been revised to apply to packages of one-half gallon or more.

Doubt inspired by the almost unbelievably large figures on monthly production and shipments of synthetic methanol during the past anti-freeze season has led to the discovery that one, and possibly more companies have been reporting to the Census Bureau on the basis of pounds instead of gallons. Inasmuch as there are approximately 7 lb. to the gallon, the Census Bureau's gallonage report reflects this inflation. The discrepancy was not detected until recently, and the Bureau now is checking up with all the reporting companies with a view to revising its reports for as many months as may be necessary.

OUTSTANDING features of the preliminary report of the Census of Dyes and Other Synthetic Organic Chemicals, 1930, just released by the U. S. Tariff Commission are: A production of 86,585,000 lb. of dyes in 1930, representing a 22 per cent decrease from the peak output in 1929; sales of 89,867,000 lb. of dyes valued at \$38,670,000, representing a decrease of 15 per cent by quantity and 16 per cent by value from sales in 1929; increase of 23 per cent in sales of unclassified and special dyes; decrease of 15 per cent in sales of domestic dyes of all classes, but decreases of only 2 per cent for vat dyes, other than indigo; 5 per cent for lake and spirit-soluble; 6 per cent for direct, and 10 per cent for basic dyes. Heavy decreases occurred in the mordant and chrome class (30 per cent) and sulphur dyes (24 per cent); sales exceeded production by 3.8 per cent in 1930, while in 1929 production exceeded sales by 5 per cent; decrease of 18 per cent in exports from 1929, and decrease of 36 per cent in imports from 1929.

The decrease in production and sales of dyes in 1930, as compared with 1929, was less, however, than the decrease in either of the depression years 1921 or 1924. A 55 per cent decrease in production and 59 per cent decrease in value occurred in the depression year of 1921 over 1920. A new production record was reached in 1923, followed by a 27 per cent decrease in production and a 26 per cent decrease in sales value in 1924. Since 1925, production and sales have gradually increased each year to a new record in 1929.

MEN IN CHEMICAL ENGINEERING

CLIFFORD BANTA, formerly engaged in research for The Barrett Company and the Standard Oil Company of Indiana, has joined the research staff of the Vacuum Oil Company of Paulsboro, N. J.

WILLIAM E. HALL has been elected president of the Duriron Company, Dayton, Ohio, succeeding to the position left vacant by the death of P. B. Schenck.

ARTHUR SCHROEDER has left the Fisher Scientific Company to join the development division of the Aluminum Company's research laboratories at New Kensington, Pa.

WILLIAM A. HAMANN, since 1885 with the Roessler & Hasslacher Chemical Company, has resigned as chairman of the board and director to retire from business and pursue his private interests.

L. P. KYRIDES, director of research for Monsanto Chemical Works, St. Louis, has been elected assistant vice-president in charge of research.

H. W. GREIDER, for several years engaged in a fellowship on magnesia products at the Mellon Institute of Industrial Research, has been appointed director of research of the Philip Carey Mfg. Company at Lockland, Ohio, where a new laboratory is under construction.

CLAUDE S. HUDSON, chief of the chemical division of the hygienic laboratory of the Public Health Service, received the Hillebrand prize for 1931 at a testimonial dinner given on March 26 by the Chemical Society of Washington.

R. T. BALDWIN, director of the Chlorine Institute and secretary of the Chemists Club, New York, has been elected treasurer of the American Chemical Society to succeed the late Dr. John E. Teeple.

ARTHUR E. PETERSEN, who was assistant director of plant operations for the Celluloid Corporation, has been advanced to the position of works manager.

A. I. Ch. Medal to Mellons

AWARD OF THE MEDAL of the American Institute of Chemists for distinguished service to chemistry to Andrew W. Mellon and Richard B. Mellon, announced on March 24, will be followed on May 9 by the presentation in Washington. The distinguished brothers, who will both be present at the presentation, have been chosen as 1931 recipients for some of their "public activities . . . which are not generally realized or appreciated," specifically the

establishment and maintenance of the Mellon Institute of Industrial Research and of the National Institute of Health.

OBITUARY

JOHN EDGAR TEEPLE, consulting chemical engineer and leading figure in the development of American potash industry, died in New York on March 23, at the age of 57 after a long illness from gallstones. Dr. Teeple made his home in Montclair, N. J., but had his consulting office in New York.

The brilliance of his work for the potash industry and of his personality overshadowed to some extent his earlier activities. Born in 1874 at Kempton,



Underwood & Underwood

Ill., he received his education at the University of Valparaiso, Ind., and Cornell, where he taught for a number of years. He came East in 1904 and developed a consulting practice while chemical director of various chemical manufacturing companies. From 1904 onward, he devoted himself entirely to the consulting practice, in which his two leading achievements were work on decolorizing carbon for the Darco Corporation and the separation of potash and borax for the American Potash & Chemical Corporation at Trona, Calif. He took charge of the latter work in 1919 and eight years later received the Perkin medal for his distinguished work there.

The high esteem of his associates resulted in his choice as president of the Chemists Club for 1921, 1922, and 1923; as treasurer of the American Chemical Society for many years, and as officer in various other technical societies. The products of his leading interests are contained in his books on "The Industrial Development of Searles Lake Brines" and on Maya astronomy, a subject to which he devoted much of his leisure.

ALFRED B. BOTFIELD, founder and past president of the company now known as Botfield Refractories Company, died at Miami, Fla., at the age of 83. Mr. Botfield was born in England, and after his education spent many years in traveling, finally coming to this country, where other industrial interests led him to investigate high-temperature cements. From this investigation he developed new commercial cements which soon found their way into industry.

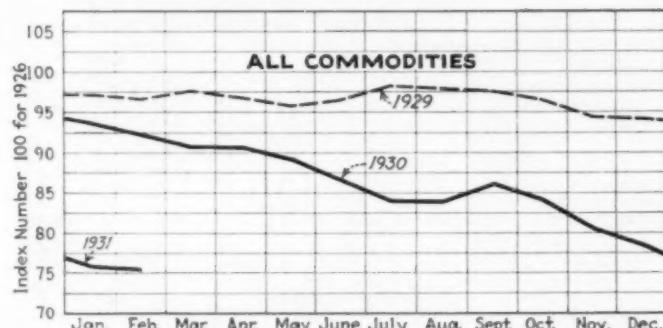
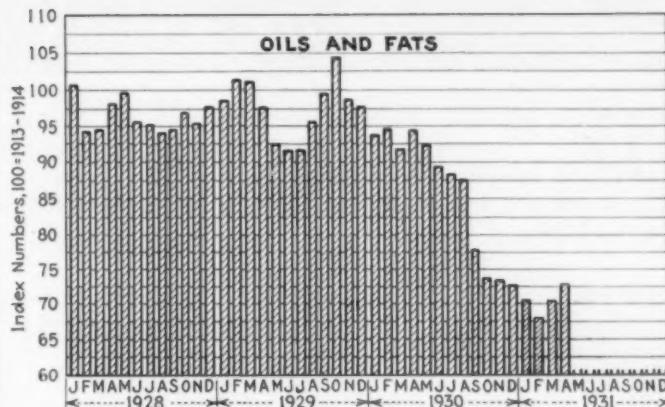
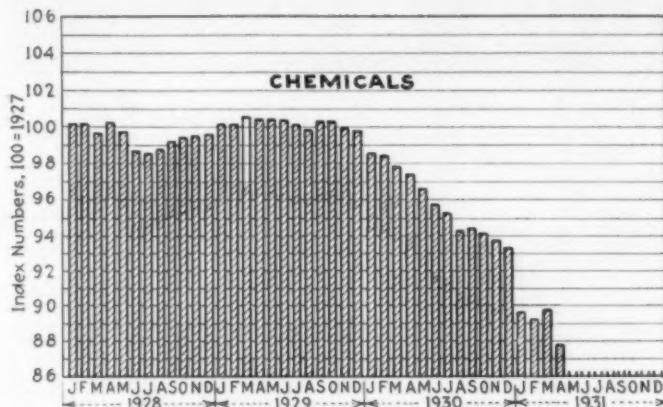
THOMAS RAYMOND EVANS, president and one of the organizers of Diamond Alkali Company, died suddenly on March 17 in Pittsburgh, his native city, at the age of 52. He was active in related branches of chemical manufacture and was the son of a pioneer Pittsburgh glass manufacturer.

PHILIP O. SCHLEUSSNER, vice-president of Roessler & Hasslacher Chemical Company, New York, and treasurer of the Manufacturing Chemists' Association, died on March 21 at Stamford, Conn., at the age of 53. Mr. Schleusser was born in Brooklyn, and after his education entered chemical manufacture by the way of the textile industry. He took charge of the platinum division of the Roessler & Hasslacher company in 1906, and from then on continued his career upward in the company's affairs. In 1923 he was elected secretary and in 1928 first vice-president. In addition he was vice-president of the Niacet Chemical Corporation.

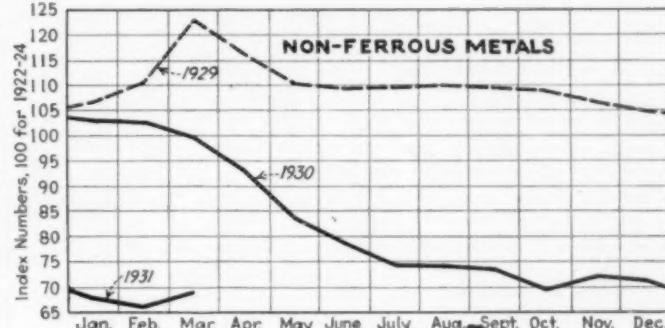
NELSON F. GREENSFELDER, advertising manager of Hercules Powder Company and authority on industrial advertising, died on April 5 after a short attack of pneumonia. Mr. Greensfelder was born in St. Louis County, Mo., in 1891, but attended Colorado College and later the Colorado School of Mines, where he was graduated in 1913. He then entered the employ of Hercules Powder Company, where his ability as a writer and advertiser caused him to be transferred to Wilmington. Here he became advertising manager in 1924 and director of *The Explosives Engineer*, published by the company. His activities and friendship pervaded the chemical industry widely. As one of the organizers and president of the National Industrial Advertising Association he represented it at the World's Advertising Conference in Berlin, 1929.

WALTER H. CROSS, president of the Kansas City Testing Laboratory and the co-developer of the petroleum cracking process bearing his name, died at his home in Kansas City, Mo., on March 24. He was 53 years old and had been ill since last December. Dr. Cross received his degree at the University Medical College in medicine and was for 17 years city chemist, but after 1911, when with his brother, Roy Cross, he became interested in oil cracking, he devoted most of his time to chemical industry. One of his outstanding achievements was his campaign against impure foods; the long series of cracking patents developed found application among many of the oil companies.

CHEM. & MET. Weighted Indexes of PRICES



U. S. Department of Labor



Engineering & Mining Journal

Sharp Break in Prices for Industrial Alcohol

SALES schedules for the majority of chemicals were unchanged during the month, but drastic reductions in quotations for denatured alcohol had a weakening influence on the solvents group. Withdrawals of ethyl alcohol for denaturation in 1930 were approximately 20 per cent below those for 1929. The decline in consuming demand, however, was even more pronounced and producers of the denatured product were faced with an unusually large carryover. In the latter part of March, attempts were made to stimulate buying interest through price concessions, and this

movement became so acute that sales were reported at 17c. per gallon in tanks as compared with the previously quoted figure of 37c. per gallon. Later values showed a partial recovery and settled at 24c. per gallon. Reduced prices were successful in disposing of a large part of accumulated stocks and in increasing consumption of alcohol at the expense of competing materials.

Following the drop in alcohol prices, methanol was reduced 5c. per gallon. Figures now available show that production of synthetic methanol increased considerably in the last four months of 1930, the total production for the year being 10,027,977 gal. Production of synthetic methanol for the first two months of the present year amounted to 2,870,556 gal., as compared with 945,135 gal. for the corresponding period of 1930.

As buying interest becomes more important as a price factor it is interesting to note that reports to the Atlantic States Shippers' Advisory Board in referring to chemicals, state that the estimate for the second quarter of 1931 indicates that shipments for the industry as a whole will show a slight increase over the first quarter of the year. Shipments of heavy chemicals are not expected to

Chem. & Met. Weighted Index of Chemical Prices

Base = 100 for 1927

This month	87.86
Last month	89.72
April, 1930	97.36
April, 1929	100.31

Quoted prices for sulphate of ammonia in the last month showed a higher average, but weakness in solvents, with lower prices for denatured alcohol, methanol, ethyl acetate, and turpentine, caused a drop in the weighted index number.

show a material increase over the first quarter of 1931. Estimates on shipments of dyes and fine chemicals indicate an improvement in the present quarter. A general summary points to an outlook for gradual improvement throughout the industry. Adjustments which have brought prices down to current levels combined with the more optimistic outlook should have a stabilizing influence on values throughout the present quarter.

The fertilizer industry offers an exception to the general rule, as the outlook is far from favorable. The National Fertilizer Association reports that tag sales in sixteen states for March were 73.6 per cent of those for March, 1930. For the four-month period, December-March, combined tag sales in these states were off 31 per cent.

Chem. & Met. Weighted Index of Prices for Oils and Fats

Base = 100 for 1927

This month	72.27
Last month	70.57
April, 1930	94.46
April, 1929	97.65

Price declines in oils and fats were more numerous than advances, but the influence of higher average prices for crude cottonseed oil and tallow more than offset lower markets for other products, and the index number was advanced.

CURRENT PRICES

in the NEW YORK MARKET

THE following prices refer to round lots in the New York market. Where it is the trade custom to sell f.o.b. works, quotations are given on that basis and are so designated. Prices are corrected to April 14.

Industrial Chemicals

	Current Price	Last Month	Last Year
Acetone, drums, lb.	\$0.10 - \$0.11	\$0.10 - \$0.11	\$0.11 - \$0.12
Acid, acetic, 28%, bbl., cwt.	2.60 - 2.85	2.60 - 2.85	3.88 - 4.03
Glacial 99%, tanks, drs.	8.98	-	-
U. S. P. reagent, c'bya.	9.23 - 9.48	9.23 - 9.48	-
Boric, bbl., lb.	.06 - .07	.06 - .07	.06 - .07
Citric, kegs, lb.	.40 - .41	.40 - .41	.46 - .47
Formic, bbl., lb.	.10 - .11	.10 - .11	.10 - .11
Gallie, tech., bbl., lb.	.50 - .55	.50 - .55	.50 - .55
Hydrofluoric 30% carb., lb.	.06 - .07	.06 - .07	.06 - .07
Lactic, 44%, tech., light, bbl., lb.	.11 - .12	.11 - .12	.11 - .12
Muriatic, 18%, tanks, cwt.	1.00 - 1.10	1.00 - 1.10	1.00 - 1.10
Nitric, 36%, carboys, lb.	.05 - .05	.05 - .05	.05 - .05
Oleum, tanks, wks., ton.	18.50 - 20.00	18.50 - 20.00	-
Oxalic, crystals, bbl., lb.	.11 - .11	.11 - .11	.11 - .12
Phosphoric, tech., c'bya, lb.	.08 - .09	.08 - .09	.08 - .09
Sulphuric, 60%, tanks, ton.	11.00 - 11.50	11.00 - 11.50	11.00 - 11.50
Tannic, tech., bbl., lb.	.23 - .35	.23 - .35	.35 - .49
Tartaric, powd., bbl., lb.	.30 - .33	.30 - .33	.37 - .39
Tungstic, bbl., lb.	1.40 - 1.50	1.40 - 1.50	1.40 - 1.50
Alcohol, ethyl 190 p.f., bbl., gal.	2.33 -	2.63 - 2.71	2.63 - 2.71
Alcohol, Butyl, tanks, lb.	1.51 -	1.51 -	.16 - .17
Alcohol, Amyl.	-	-	-
From Pentane, tanks, lb.	236 -	236 -	.236 -
Denatured, 188 proof	-	-	-
No. 1 special dr., gal.	.27 -	.39 -	.43 -
No. 5, 188 proof, dr., gal.	.27 -	.39 -	.44 -
Alum, ammonia, lump, bbl., lb.	.01 - .04	.01 - .04	.01 - .04
Chrome, bbl., lb.	.04 - .05	.04 - .05	.05 - .06
Potash, lump, bbl., lb.	.03 - .04	.03 - .04	.03 - .04
Aluminum sulphate, com., bags, cwt.	1.25 - 1.40	1.25 - 1.40	1.40 - 1.45
Iron free, bg., cwt.	1.90 - 2.00	1.90 - 2.00	1.90 - 2.00
Aqua ammonia, 26%, drums, lb.	.02 - .03	.02 - .03	.03 - .04
tanks, lb.	.02 - .02	.02 - .02	-
Ammonia, anhydrous, cyl., lb.	.15 - .15	.15 - .15	.15 - .15
tanks, lb.	.05 -	.05 -	-
Ammonium carbonate, powd.	-	-	-
tech., casks, lb.	.10 - .11	.10 - .11	.11 - .12
Sulphate, wks., cwt.	1.75 -	1.60 -	2.10 -
Amylacetate tech., tanks, lb., gal.	.22 -	.22 -	.22 -
Antimony Oxide, bbl., lb.	.08 - .10	.08 - .10	.09 - .10
Arsenic, white, powd., bbl., lb.	.04 - .04	.04 - .04	.04 - .04
Red, powd., kegs, lb.	.09 - .10	.09 - .10	.09 - .10
Barium carbonate, bbl., ton.	58.00 - 60.00	58.00 - 60.00	58.00 - 60.00
Chloride, bbl., ton.	63.00 - 65.00	63.00 - 65.00	64.00 - 70.00
Nitrate, cask, lb.	.07 - .07	.07 - .07	.07 - .07
Blane fixe, dry, bbl., lb.	.03 - .04	.03 - .04	.03 - .04
Bleaching powder, f.o.b., wks., drums, cwt.	2.00 - 2.10	2.00 - 2.10	2.00 - 2.10
Borax, bbl., lb.	.03 -	.03 -	.03 -
Bromine, c.s., lb.	.36 - .38	.36 - .38	.45 - .47
Calcium acetate, bags.	2.00 -	2.00 -	4.50 -
Arsenate, dr., lb.	.06 - .07	.07 - .10	.07 - .08
Carbide drums, lb.	.05 - .06	.05 - .06	.05 - .06
Chloride, fused, dr., wks., ton.	20.00 -	20.00 -	20.00 -
Flake, dr., wks., ton.	22.75 -	22.75 -	22.75 -
Phosphate, bbl., lb.	.08 - .08	.08 - .08	.08 - .08
Carbon bisulphide, drums, lb.	.05 - .06	.05 - .06	.05 - .06
Tetrachloride drums, lb.	.06 - .07	.06 - .07	.06 - .07
Chlorine, liquid, tanks, wks., lb.	.01 -	.01 -	.02 -
Cylinders.	.04 - .06	.04 - .06	.04 - .06
Cobalt oxide, cans, lb.	1.75 - 1.85	1.75 - 1.85	2.10 - 2.2
Copperas, bgm., f.o.b. wks., ton.	13.00 - 14.00	13.00 - 14.00	15.00 - 16.00
Copper carbonate, bbl., lb.	.08 - .18	.08 - .17	.13 - .20
Cyanide, tech., bbl., lb.	.41 - .46	.41 - .46	.45 - .46
Sulphate, bbl., cwt.	4.25 - 4.50	4.25 - 4.50	5.50 - 6.00
Cream of tartar, bbl., lb.	.23 - .24	.23 - .24	.26 - .27
Diethyleneglycol, dr., lb.	.14 - .16	.14 - .16	.11 - .13
Epsom salt, dom., tech., bbl., cwt.	1.70 - 2.00	1.70 - 2.00	1.75 - 2.00
Imp., tech., bags, cwt.	1.15 - 1.25	1.15 - 1.25	1.15 - 1.25
Ethyl acetate, drums, lb.	.08 -	.085 -	.121 -
Formaldehyde, 40%, bbl., lb.	.06 - .07	.06 - .07	.07 - .08
Furfural, dr., contract, bbl., lb.	.10 - .12	.10 - .12	.15 - .17
Fuel oil, crude, drums, gal.	1.30 - 1.40	1.30 - 1.40	1.30 - 1.40
Refined, dr., gal.	1.90 - 2.00	1.90 - 2.00	1.93 - 2.00
Glaubers salt, bags, cwt.	1.10 - 1.20	1.10 - 1.20	1.00 - 1.10
Glycerine, c.p., drums, extra, lb.	1.24 - 1.3	1.24 - 1.3	1.4 - .15
Led:	-	-	-
White, basic carbonate, dr., casks, lb.	.07 -	.07 -	.08 -
White, basic sulphate, sec., lb.	.07 -	.07 -	.07 -
Red, dry, sec., lb.	.08 -	.08 -	.09 -
Lead acetate, white crys., bbl., lb.	11 - 12	11 - 12	13 - 134
Lead arsenate, powd., bbl., lb.	11 - 14	13 - 14	12 - 14
Lime, chem., bulk, ton.	8.50 -	8.50 -	8.50 -
Litharge, p.wd., csk, lb.	.07 -	.07 -	.08 -
Ithopone, bags, lb.	.04 - .05	.04 - .05	.05 - .06
Magnesium carb., tech., bags, lb.	.06 - .06	.06 - .06	.06 - .06

	Current Price	Last Month	Last Year
Methanol, 95%, tanks, gal.	.33 -	.38 -	.38 -
97%, tanks, gal.	.34 -	.39 -	.45 -
Synthetic, tanks, gal.	.40 -	.40 -	.40 - .45
Nickel salt, double, bbl., lb.	10 - 11	10 - 11	13 - 13
Single, bbl., lb.	10 - 11	10 - 11	13 - 13
Orange mineral, csk, lb.	10 -	10 -	11 -
Phosphorus, red, cases, lb.	.42 -	.42 -	.42 - .44
Yellow, cases, lb.	.31 - .32	.31 - .32	.31 - .32
Potassium bichromate, casks, lb.	.09 - .09	.09 - .09	.09 - .09
Carbonate, 80-85%, calc., csk, lb.	.05 - .06	.05 - .06	.05 - .06
Chlorate, powd., lb.	.08 - .08	.08 - .08	.08 - .09
Cyanide, c.s., lb.	.55 - .57	.55 - .57	.52 - .55
Fras sorts, csk, lb.	.08 - .09	.08 - .09	.09 - .09
Hydroxide (c'atic potash) dr., lb.	.06 - .06	.06 - .06	.06 - .06
Muriate, 80% bags, ton.	37.15 -	37.15 -	36.75 -
Nitrate, bbl., lb.	.05 - .06	.05 - .06	.06 - .07
Permanganate, drums, lb.	.16 - .16	.16 - .16	.16 - .16
Prussiate, yellow, casks, lb.	.18 - .19	.18 - .19	.18 - .19
Salt ammoniac, white, casks, lb.	.04 - .05	.04 - .05	.04 - .05
Salsoda, bbl., cwt.	.90 - .95	.90 - .95	.90 - .95
Salt cake, bulk, ton.	15.00 - 18.00	15.00 - 18.00	22.00 - 25.00
Soda ash, light, 58%, bags, contract, cwt.	1.15 -	1.15 -	1.32 -
Dense, bags, cwt.	1.17 -	1.17 -	1.35 -
Soda, caustic, 76%, solid, drums, contract, cwt.	2.50 - 2.75	2.50 - 2.75	2.90 - 3.00
Acetate, works, bbl., lb.	.04 - .05	.04 - .05	.03 - .04
Bicarbonate, bbl., cwt.	1.85 - 2.00	1.85 - 2.00	2.00 - 2.25
Bichromate, casks, lb.	.07 - .07	.07 - .07	.07 - .07
Bisulphite, bulk, ton.	14.00 - 16.00	14.00 - 16.00	16.00 - 18.00
Bisulphite, bbl., lb.	.03 - .04	.03 - .04	.03 - .04
Chlorate, kegs, lb.	.05 - .07	.05 - .07	.07 - .08
Chloride, tech., ton.	12.00 - 14.75	12.00 - 14.75	12.00 - 14.00
Cyanide, cases, dom., lb.	.16 - .17	.16 - .17	.18 - .22
Fluoride, bbl., lb.	.08 - .08	.08 - .08	.08 - .09
Hyposulphite, bbl., lb.	2.40 - 2.50	2.40 - 2.50	2.40 - 2.50
Nitrate, bags, cwt.	.05 -	.05 -	.16 -
Phosphate, dibasic, bbl., lb.	.0265 - .03	.0265 - .03	.03 - .03
Prussiate, yel. drums, lb.	.11 - .12	.11 - .12	.11 - .12
Silicate (30%), drums, cwt.	.60 - .70	.60 - .70	.60 - .70
Sulphide, fused, 60-62%, dr., lb.	.024 - .03	.024 - .03	.03 - .04
Sulphite, eyna, bbl., lb.	.03 - .03	.03 - .03	.02 - .03
Sulphur, crude at mine, bulk, ton	18.00 -	18.00 -	18.00 -
Chloride, dr., lb.	.05 - .06	.05 - .06	.05 - .06
Dioxide, cyl., lb.	.06 - .07	.06 - .07	.07 - .08
Flour, bag, cwt.	1.55 - 3.00	1.55 - 3.00	1.55 - 3.00
Tin dichloride, bbl., lb.	nom.	nom.	nom.
Oxide, bbl., lb.	.28 -	.29 -	.40 -
Crystals, bbl., lb.	.25 -	.26 -	.31 -
Zinc chloride, gran., bbl., lb.	.06 - .06	.06 - .06	.06 - .06
Carbonate, bbl., lb.	.10 - .11	.10 - .11	.10 - .11
Cyanide, dr., lb.	.41 - .42	.41 - .42	.40 - .41
Dust, bbl., lb.	.06 - .07	.06 - .07	.07 - .08
Zinc oxide, lead free, bag, lb.	.16 -	.06 -	.06 -
5% lead sulphate, bags, lb.	.06 -	.06 -	.06 -
Sulphate, bbl., cwt.	3.00	3.25	2.75 - 3.00

Oils and Fats

	Current Price	Last Month	Last Year
Castor oil, No. 3, bbl., lb.	\$0.10 - \$0.11	\$0.10 - \$0.11	\$0.12 - \$0.13
Chinawood oil, bbl., lb.	.07 -	.07 -	.11 -
Coconut oil, Ceylon, tanks, N.Y., lb.	.05 -	.04 -	.06 -
Corn oil, crude, tanks, (f.o.b. mill), lb.	.07 -	.07 -	.07 -
Cottonseed oil, crude (f.o.b. mill), tanks, lb.	.06 -	.06 -	.07 -
Linseed oil, raw, car lots, bbl., lb.	.09 -	.094 -	.144 -
Palm, Lagos, casks, lb.	.06 -	.06 -	.07 -
Niger, casks, lb.	.05 -	.05 -	.07 -
Palm Kernel, bbl., lb.	.05 -	.05 -	.07 -
Peanut oil, crude, tanks (mill), lb.	.07 -	.07 -	.07 -
Rapeseed oil, refined, bbl., gal.	.54 - .56	.56 - .58	.68 - .70
Soya bean, tank (f.o.b. Coast), lb.	nom.	.08 -	.09 -
Sulphur (olive foots), bbl., lb.	.05 -	.06 -	.07 -
Cod, Newfoundland, bbl., gal.	.42 - .45	.42 - .45	.55 - .57
Menhaden, light pressed, bbl., gal.	.34 - .36	.34 - .36	.63 - .65
Crude, tanks (f.o.b. factory), gal.	nom.	nom.	nom.
Whale, crude, tanks, gal.	.78 -	.78 -	.80 -
Grease, yellow, loose, lb.	.03 -	.02 -	.05 -
Oleo stearine, lb.	.08 -	.07 -	.09 -
Red oil, distilled, d.p., bbl., lb.	.08 -	.08 -	.10 -
Tallow, extra, loose, lb.	.05 -	.05 -	.06 -

Coal-Tar Products

	Current Price	Last Month	Last Year
Alpha-naphthol, crude, bbl., lb.	0.60 - \$0.65	\$0.60 - \$0.65	\$0.60 - \$0.62
Refined, bbl., lb.	80 - 85	80 - 85	80 - 85
Alpha-naphthylamine, bbl., lb.	32 - 34	32 - 34	32 - 34
Aniline oil, drums, extra, lb.	14 - 15	14 - 15	15 - 16
Aniline salts, bbl., lb.	1 - 25	24 - 25	24 - 32
Anthracene, 80%, drums, lb.	60 - 65	60 - 65	60 - 65

Coal-Tar Products (Continued)

	Current Price	Last Month	Last Year
Benzaldehyde, U.S.P., dr., lb.	1.10 - 1.25	1.10 - 1.25	1.15 - 1.25
Benzidine base, bbl., lb.	.65 - .67	.65 - .67	.65 - .67
Benzoic acid, U.S.P., kgs, lb.	.57 - .60	.57 - .60	.57 - .60
Benzyl chloride, tech., dr., lb.	.30 - .35	.30 - .35	.30 - .35
Benzol, 90%, tanks, works, gal.	.20 - .21	.20 - .21	.22 - .23
Beta-naphthol, tech., drums, lb.	.22 - .24	.22 - .24	.22 - .24
Cresol, U.S.P., dr., lb.	.14 - .17	.14 - .17	.14 - .17
Cresylic acid, 97%, dr., wks, gal.	.54 - .58	.54 - .58	.60 - .70
Diethylaniline, dr., lb.	.55 - .58	.55 - .58	.55 - .58
Dinitrophenol, bbl., lb.	.29 - .30	.29 - .30	.30 - .31
Dinitrotoluene, bbl., lb.	.16 - .17	.16 - .17	.16 - .17
Dip oil, 25% dr., gal.	.26 - .28	.26 - .28	.26 - .28
Diphenylamine, bbl., lb.	.38 - .40	.38 - .40	.39 - .40
H-acid, bbl., lb.	.65 - .70	.65 - .70	.68 - .70
Naphthalene, flake, bbl., lb.	.034 - .044	.034 - .044	.044 - .055
Nitrobenzene, dr., lb.	.081 - .09	.081 - .09	.081 - .10
Para-nitraniline, bbl., lb.	.51 - .55	.51 - .55	.51 - .55
Para-nitrotoluine, bbl., lb.	.29 - .30	.29 - .31	.29 - .31
Phenol, U.S.P., drums, lb.	.144 - .15	.144 - .15	.144 - .15
Pieric acid, bbl., lb.	.30 - .40	.30 - .40	.30 - .40
Pyridine, dr., lb.	.150 - 1.75	.150 - 1.80	.150 - 1.80
R-salt, bbl., lb.	.40 - .44	.40 - .44	.44 - .45
Resorcinol, tech., kegs, lb.	.15 - 1.25	.15 - 1.25	.15 - 1.25
Salicylic acid, tech., bbl., lb.	.33 - .35	.33 - .35	.33 - .35
Solvent naphtha, w.w., tanks, gal.	.25 - .30	.25 - .30	.28 - .30
Tolidine, bbl., lb.	.86 - .88	.86 - .88	.91 - .93
Toluene, tanks, works, gal.	.30 - .32	.30 - .32	.35 - .37
Xylene, com., tanks, gal.	.25 - .28	.25 - .28	.28 - .30

Miscellaneous

	Current Price	Last Month	Last Year
Barytes, grd., white, bbl., ton	\$23.00-\$25.00	\$23.00-\$25.00	\$23.00-\$25.00
Casein, tech., bbl., lb.	.074 - .11	.084 - .11	.134 - .15
China clay, dom., f.o.b. mine, ton	8.00 - 20.00	8.00 - 20.00	8.00 - 20.00
Dry colors:			
Carbon gas, black (wks.), lb.	.03 - .20	.03 - .20	.05 - .22
Prussian blue, bbl., lb.	.35 - .36	.35 - .36	.35 - .36
Ultramine blue, bbl., lb.	.06 - .32	.06 - .32	.03 - .35
Chrome green, bbl., lb.	.27 - .28	.27 - .28	.27 - .30
Carmine red, tins, lb.	5.00 - 5.40	5.00 - 5.40	6.00 - 6.50
Para toner, lb.	.75 - .80	.75 - .80	.77 - .80
Vermilion, English, bbl., lb.	1.70 - 1.80	1.70 - 1.80	1.90 - 2.00
Chrome yellow, C. P., bbl., lb.	164 - 17	164 - 17	17 - 17½
Feldspar, No. 1 (f.o.b. N.C.), ton	6.50 - 7.50	6.50 - 7.50	6.50 - 7.50
Graphite, Ceylon, lump, bbl., lb.	.07 - .08	.07 - .08	.04 - .05
Cure copal Congo, bags, lb.	.06 - .08	.06 - .08	.074 - .08
Manila, bags, lb.	.16 - .17	.16 - .17	.16 - .17
Damar, Batavia, canes, lb.	.16 - .164	.16 - .19	.18 - .19
Kauri No. 1 cases, lb.	.45 - .48	.45 - .48	.48 - .53
Kieselguhr (f.o.b. N.Y.), lb.	50.00 - 55.00	50.00 - 55.00	50.00 - 55.00
Magnesite, calc., ton	40.00 - .	40.00 - .	40.00 - .
Pumice stone, lump, bbl., lb.	.05 - .07	.05 - .08	.05 - .07
Imported, casks, lb.	.03 - .40	.03 - .40	.03 - .35
Rosin, H., bbl.	6.35 - .	6.00 - .	8.40 - .
Turpentine, gal.	.544 - .	.53 - .	.55 - .
Shellac, orange, fine, bags, lb.	.41 - .42	.41 - .42	.55 - .58
Bleached, bonedry, bags, lb.	.30 - .31	.30 - .31	.38 - .40
T. N. bags, lb.	.18 - .19	.18½ - .19	.27 - .28
Soapstone (f.o.b. Vt.), bags, ton	10.00 - 12.00	10.00 - 12.00	10.00 - 12.00
Talc, 200 mesh (f.o.b. Vt.), ton	8.00 - 8.50	8.00 - 8.50	9.50 - .
300 mesh (f.o.b. Ga.), ton	7.50 - 10.00	7.50 - 10.00	7.50 - 11.00
225 mesh (f.o.b. N.Y.), ton	13.75 - .	13.75 - .	13.75 - .

	Current Price	Last Month	Last Year
Wax, Bayberry, bbl., lb.	\$0.20 - \$0.22	\$0.21 - \$0.24	\$0.27 - \$0.29
Beeswax, ref., light, lb.	.26 - .30	.26 - .30	.36 - .38
Candelilla, bags, lb.	.13½ - .14	.13½ - .14	.19 - .20
Carnauba, No. 1, bags, lb.	.21½ - .22	.21½ - .22	.31 - .32
Paraffine, crude			
105-110 m.p., lb.	.03½ - .03½	.03½ - .03½	.04½ - .05

Ferro-Alloys

	Current Price	Last Month	Last Year
Ferrotitanium, 15-18%, ton	\$200.00 -	\$200.00 -	\$200.00 -
Ferromanganese, 78-82%, ton	80.00 - 85.00	80.00 - 85.00	94.00 - 99.00
Spiegeleisen, 19-21%, ton	30.00 -	30.00 -	33.00 -
Ferrosilicon, 14-17%, ton	39.00 -	39.00 -	45.00 -
Ferrotungsten, 70-80%, lb.	1.10 -	1.10 -	1.45 -
Ferrovanadium, 30-40%, lb.	3.15 - 3.50	3.15 - 3.50	3.15 - 3.50

Non-Ferrous Metals

	Current Price	Last Month	Last Year
Copper, electrolytic, lb.	\$0.10 -	\$0.10 -	\$0.17½ -
Aluminum, 96-99%, lb.	.233 -	.233 -	.24 - .25
Antimony, Chin. and Jap., lb.	.074 -	.074 -	.08 -
Nickel, 99% lb.	.55 -	.55 -	.55 -
Monel metal, blocks, lb.	.28 -	.28 -	.28 -
Tin, 5-ton lots, Straits, lb.	.26 -	.2715 -	.36½ -
Lead, New York, spot, lb.	.045 -	.045 -	.055 -
Zinc, New York, spot, lb.	.0435 -	.0435 -	.0495 -
Silver, commercial, oz.	.28½ -	.295 -	.42½ -
Cadmium, lb.	.55 -	.55 -	.80 - .85
Bismuth, ton lots, lb.	1.40 -	1.40 -	1.70 -
Cobalt, lb.	2.50 -	2.50 -	2.50 -
Magnesium, ingots, 99%, lb.	.48 -	.48 -	.85 - 1.10
Platinum, ref., oz.	30.00 -	30.00 -	46.00 -
Palladium ref., oz.	19.00 - 21.00	19.00 - 21.00	30.00 - 35.00
Mercury, flask, 75 fl.	102.00 -	100.00 -	113.00 -
Tungsten powder, lb.	1.65 -	1.65 -	1.70 - 1.75

Ores and Semi-finished Products

	Current Price	Last Month	Last Year
Bauxite, crushed, wks., ton	\$6.50 - \$8.25	\$6.50 - \$8.25	\$7.50 - \$8.00
Chrome ore, c.f. post, ton	19.00 - 24.00	19.00 - 24.00	21.50 - 25.00
Coke, fdry., f.o.b. ovens, ton	2.75 - 2.85	2.75 - 3.85	2.75 - 2.85
Fluorspar, gravel, f.o.b. Ill., ton	17.25 - 20.00	17.25 - 20.00	18.00 - 20.00
Manganese ore, 50% Mn, e.i.f. Atlantic Ports unit	25 - 27	25 - 27	.31 - .36
Molybdenite, 85% MoS ₂ per lb.	.35 - 40	.35 - 40	.48 - .50
MoS ₂ , N. Y., lb.			
Monasite, 6% of ThO ₂ , ton	60.00 -	60.00 -	60.00 -
Pyrites, Span., fines, c.f., unit	.13 -	.13 -	.13 -
Rutile, 94-96% TiO ₂ , lb.	.10 - .11	.10 - .11	.10 - .11
Tungsten, scheelite, 60% WO ₃ and over, unit	12.00 - 12.50	12.00 - 12.50	15.25 - 16.50

CURRENT INDUSTRIAL DEVELOPMENTS

New Construction and Machinery Requirements

Aluminate Factory—Aluminate Co., 135-26 Hillside Ave., Jamaica, N. Y., will build a factory at 132nd Ave. and 91st St. Estimated cost to exceed \$40,000. H. T. Jeffery, 90-50 Parsons Blvd., Jamaica, is architect. Work will be done by day labor and separate contracts.

Asbestos Plant—Smith Faris Co., R. I. Smith, Pres., 1150 Hodgkiss St., Pittsburgh, Pa., manufacturers of asbestos, awarded contract for a 1 story, 26 x 82 ft. plant to A. Phillip, 3122 Brighton Rd. N. S., Pittsburgh. Estimated cost \$40,000.

Asphalt Plant—Dept. of Public Works, City Hall, Portsmouth, N. H., had plans prepared for the construction of a hot asphalt plant including motors, mixer, pug mixer, bins, elevator, screens, kettle 1,000 gal. capacity, heater, pump and dryer. Estimated cost to exceed \$40,000. Private plans.

Brass Foundry—Hock & Volk Brass Foundry, c/o G. S. Hock and R. K. Volk, Baltimore, Md., has work under way on the construction of a

plant for the production of brass bronze, and aluminum castings at 46 East York St.

a 2 story, 85 x 400 ft. warehouse on East 15th St. Walker & Eisen, Western Pacific Bldg., Los Angeles, are architects.

Glauber Salt Building—Merrimac Chemical Co., Everett, Mass., awarded contract for a 2 story, 60 x 150 ft. glauber building, plant unit at Chemical Lane to A. C. Peters Co. Inc., 46 Cornhill, Boston. Estimated cost \$65,000. Private plans.

Clay Products Plant—Mineral Wells Clay Products Co., c/o A. E. Eaton, Pres., Mineral Wells, Tex., is having preliminary plans prepared for the construction of a clay products plant. Estimated cost \$100,000.

Coke Plant—Fields Chemical Corp., 122 Financial Center Bldg., Los Angeles, Calif., plans the construction of first unit of metallurgical coke plant, 20 ton daily capacity.

Crosoing Plant—J. J. Seguin Co., St. Lambert, Que., will soon award contract for two additions to present plant, one building to house crosoing cylinder and the other to contain machinery and equipment. Estimated cost \$150,000.

Gas Plant—Cape Cod Gas Co., Hyannis, Mass., awarded contract for an illuminating gas plant at Barnstable to J. H. Burke, 221 High St., Wareham. Estimated cost to exceed \$40,000.

Gas Plant—City Gas Co., W. C. Duffield, Mgr., London, Ont., plans to expend \$1,000,000 on additional plant and equipment including large steel gas holder, retorts and general equipment for manufacturing gas. Private plans.

Gas Plant—Consolidated Gas Co., Irving Pl., New York, N. Y., acquired a site and plans the construction of a central distribution gas plant on East 17th St. Maturity indefinite.

Gas Plant—W. A. Howard and S. J. Campbell, Kansas City, Mo., have been granted franchise and will construct a plant for vaporization of butane gas, also distribution mains at Caruthersville. Private plans.

Gas Plant—Martinsville Gas Co., Martinsville, Va., N. H. Gilbert, Pres., Meadowbrook, Pa., recently organized to generate, manufacture, distribute and sell natural, manufactured or mixed gas, plans the construction of a gas plant.

Gas Mixing Plant, Etc.—Niagara & Hudson Power Co., Warren St., Syracuse, N. Y., plans the construction of gas pipe line from Oswego to Syracuse including gas mixing plant. Estimated cost to exceed \$300,000. Maturity soon.

Glass Plant—Lotus Glass Co., Barnesville, O., plans the construction of a 1 story, 30 x 60 ft. factory unit to provide added facilities for decorating and silver departments. Estimated cost \$40,000.

Gypsum Factory—United States Gypsum Co., 111 West Washington St., Chicago, Ill., plans the construction of a 1 story factory unit for the manufacture of patented metal arch at Warren, O. Estimated cost \$100,000.

Kaolin Factory—M. B. Miller & Co., Gonzales, Tex., plans construction of a factory. Kaolin is a clay product used in refining crude oil. Machinery and equipment for mining and shipping clay will be required.

Chemistry Building—Institute of Paper Chemistry, Appleton, Wis., awarded contract for the construction of a 2 story, 56 x 114 ft. paper chemistry building, to B. B. Gantner, Oshkosh. Estimated cost \$100,000.

Laboratories (Chemistry, Physics and Biology)—John Carroll University, J. J. Bernet, Chm. of Bd., Committee, West 30th St. and Carroll Ave., Cleveland, O., awarded contract for the construction of a group of college buildings including, 83 x 152 ft. chemistry building, 70 x 310 ft. physics and biology building, etc. to Hunkin-Conkey Construction Co., Newman-Stern Bldg., Cleveland. Estimated cost \$2,000,000.

Laboratory (Bacteriological)—Bd. of Chosen Freeholders, Court House, Jersey City, N. J., awarded contract for the construction of a 1 story bacteriological laboratory on Foye Pl. to E. M. Johnson, 706 Bergen Ave., Jersey City.

Laboratory (Diesel Engine)—Bureau of Yards & Docks, Navy Dept., Washington, D. C., received lowest bid for the construction of a Diesel engine laboratory at Naval submarine base, New London, Conn. from Charles Smith & Sons, 101 Water St., Derby, Conn. \$24,900.

Laboratory (Hydraulic)—Bureau of Standards, Washington, D. C., awarded contract for the construction of a hydraulic laboratory to Stofflet & Tillotson, 14 West Chelton Ave., Philadelphia, Pa. \$284,887.

Laboratory (Physical and Chemical)—Mount Holyoke College, M. E. Wooley, Pres., South Hadley, Mass., awarded contract for a 3 story, 55 x 135 ft. physical and chemical laboratory to E. J. Pinney Inc., 220 Dwight St., Springfield. Estimated cost \$200,000.

Laboratory—Bd. of Education, Musselman Bldg., Quincy, Ill., will soon award contract for the construction of a 3 story 224 x 310 ft. school including laboratory, etc. on 14th St. Estimated cost \$1,350,000. J. D. Chubb, 109 North Dearborn St., Chicago, Ill., is architect. Behrensmeyer & Hafener, W. C. U. Bldg., Quincy, are associate architects.

Laboratory—California Institute of Technology, Pasadena, Calif., awarded contract for the construction of a laboratory on California St. to W. C. Crowell, 495 South Broadway, Los Angeles. Estimated cost \$150,000.

Laboratory—Madison Hospital, North Madison, Ind., awarded contract for the construction of a hospital including laboratory to E. Ainsworth & Son Construction Co., 1248 Fulman St., Terre Haute. Estimated cost \$150,000.

Laboratory—Mead-Johnson Co., Evansville, Ind., awarded contract for a 2 story, 40 x 65 ft. laboratory at St. Joe Ave. and Ohio St. to Hoffman Construction Co., Union Bank Bldg., Evansville. Estimated cost \$42,000.

Factory—J. C. Virden Co., 6103 Longfellow Ave., Cleveland, O. (electrical goods), awarded contract for a 2 story, 35 x 153 ft. addition to factory to G. A. Rutherford Co., 2725 Prospect Ave., Cleveland. Estimated cost \$40,000. Lacquer ovens, spray baths and tumbling barrels will be required.

Leather Factory—Carr Leather Co., 111 Foster St., Peabody, Mass., is receiving bids for the construction of a 5 story, 45 x 100 ft. factory. Estimated cost to exceed \$40,000. Private plants.

Lime Hydrating Plant—Louisiana Lime & Stone Co., c/o E. B. Floss, Citizens Bank & Trust Bldg., Bastrop, La., plans a new lime hydrating plant. Estimated cost \$75,000. Owner also has rock properties in Boone County, Ark. and will develop for raw material supply, installing, mining, conveying and other machinery.

Paper Mill—American Writing Paper Co. Inc., Holyoke, Mass., plans extensions and improvements to paper mill to include electrification of part of plant. Estimated cost \$100,000. Private plans.

Paper Plant—Continental Paper Co., River Rd., Bogota, N. J., awarded contract for the construction of a paper plant at Ridgewood Park to Claus, Ahrens & Co. Inc., 73 Ulmard St., East Rutherford. Estimated cost \$40,000.

Paper Plant—Kupfer Bros. Co., Riverdale, Northbridge, Mass., had plans prepared for addition to paper factory. Estimated cost \$60,000. Private plans.

Pottery Plant—C. C. Thompson Pottery Co., East Liverpool, O., awarded contract for a 2 story 50 x 150 ft. pottery plant on River Rd. to Potters Lumber Co., East Liverpool; also tunnel kiln of Robertson type, 135 ft. long to H. L. Dixon Co., Rosslyn Rd., Pittsburgh, Pa. Estimated cost \$50,000 and \$40,000 respectively.

Plant—Provincial Government, Edmonton, Alta., plans the construction of a semi-commercial plant, manufacturing benzine from waste gas at Calgary. D. E. H. Boomer, in charge.

Gasoline Extraction Plant—Apache Refining Co., Los Angeles, Calif., c/o B. S. McFarland, Sunray Oil Co., Exchange National Bank Bldg., Tulsa, Okla., has work under way on a 5,000 bbl. 30,000,000 cu. ft. gasoline extraction plant at Altman, Tex. Estimated cost \$200,000.

Oil Plant—Reilly Whitman & Walton, Canal Bank Bldg., Conshohocken, Pa., awarded contract for a 1 and 2 story, 122 x 144 ft. oil plant to E. A. Reeves, 107 York Rd., Abington, Pa.

Refinery—Amarillo Producers & Refiners Association, J. D. and J. W. Wrather, Amarillo, Tex., is having preliminary plans prepared for the construction of refineries at Overton, and Longview. Estimated cost \$100,000 and \$150,000 respectively. Private plans.

Refinery—Gulf Refining Co., c/o E. H. Bison, Asst. Engr. of Const., Battery Park Bldg., New York, N. Y., had plans made for a 23 steel plate tank, 8,154,600 gal. capacity, also warehouse, gasoline station, pump house, truck filling building, boiler house and machine shop, etc. at West Third St. and Jefferson Ave. Estimated cost \$1,000,000.

Refinery (Cotton Oil)—Proctor & Gamble Co., Gwynne Bldg., Cincinnati, O., plans alterations to Portsmouth Cotton Oil refining plant at Portsmouth, Va. with possibility of large addition. Estimated cost to exceed \$40,000. Maturity indefinite.

Refinery (Oil)—McColl-Frontenac Ltd., Notre Dame St. E., Montreal, Que., plans the construction of a tank, 2,000,000 gal. capacity in connection with oil refinery at St. John, N. B. Estimated cost \$100,000.

Refinery (Oil)—Preussag & Elverath Oil Co's, c/o A. McKee & Co., 2422 Euclid Ave., Cleveland, O., Contrs., awarded contract for the construction of an oil refinery (Dubbs process) at Misburg (near Hamburg) Germany.

Refinery (Oil and Gasoline)—C. W. Young, Archer City, Tex., will build an oil and gasoline refinery. Estimated cost \$85,000.

Rod Mill and Copper Wire Factory—Nichols Copper Co., 25 Broad St., New York, N. Y., c/o J. P. Dwyer, Mgr. P. O. Box 1372, El Paso, Tex., plans the construction of a rod mill and copper wire factory at El Paso. Estimated cost \$1,500,000.

Roofing Products Plant—Barrett & Co., 36th St. and Grays Ferry Ave., Philadelphia, Pa., awarded contract for the construction of a plant for the manufacture of roofing products to Austin Co., 16112 Euclid Ave., Cleveland, O. Estimated cost \$150,000.

Salt Rock Mine—Louisiana Development Co., C. R. Walters, Supt., subsidiary of Cary Mining Interests, Hutchinson, Kan., has work under way on the construction of a 183 x 78 ft. breaker building for salt rock mine, Winnfield, La. Work will be done by owners forces.

Slag Grinding Plant—Standard Slag Co., City Bank Bldg., Youngstown, O., plans the construction of a plant for grinding slag into various grades at Hollidays Cove, W. Va. Estimated cost \$40,000.

Skimming Plant—G. Constantine, 1330 Terrace Dr., Tulsa, Okla., plans the construction of a skimming plant, 6,000 bbls. daily capacity near oil refinery plant, Tyler, Tex. Estimated cost \$400,000. Private plans.

Tannery Addition—Elk Tanning Co., 2 Park Ave., New York, N. Y., awarded contract for two additions to tannery, 50 x 160 and 74 x 100 ft. at Ridgway, Pa. to Hyde-Murphy Construction Co., Ridgway. Estimated cost to exceed \$40,000.

Timber Treating Plant—Union Pacific R.R. Co., 15th and Dodge Sts., Omaha, Neb., plans improvements to timber treating plant at Pocatello, Idaho; also water treating plants, 18,000 gal. per day capacity at Burley and Bancroft. Estimated cost \$30,000 and \$54,000 respectively. G. J. Adamson, Omaha, Ch. Engr.

Waterproofing Compound Plant—Tremco Mfg. Co. of Canada Ltd., c/o W. H. Reid, 81 Victoria St., Toronto, Ont., awarded contract for the construction of a 2 story, 45 x 100 ft. plant for the manufacture of caulking, glazing and waterproofing compounds at Leaside to Gatehouse Bros. Ltd., 86 Adelaide St. E., Toronto. Estimated cost \$50,000.

INDUSTRIAL NOTES

LINCOLN ELECTRIC COMPANY, Cleveland, Ohio, has moved its Chicago office at 1455 West 37th St.

MERIAM COMPANY, Cleveland, Ohio, have appointed Mayer & Oswald representatives in Chicago.

TIMKEN STEEL & TUBE COMPANY, Canton, Ohio, has appointed Walter H. Wiewel sales manager, with headquarters at Canton.

NORTHERN ENGINEERING WORKS, Detroit, Mich., has opened an office at 1940 East 6th St., Cleveland.

ISAAC WINKLER & BROTHER COMPANY has been acquired by the Pittsburgh Plate Glass Company, to function as a unit of the Columbia Alkali Company. The personnel will be retained, with Eli Winkler as executive vice-president, and W. I. Galliher, director of sales of the Columbia Alkali Company.

GENERAL CERAMICS COMPANY has moved its home office to 71 West 35th St., New York.

PURITAN COMPRESSED GAS CORPORATION is the new name of the Kansas City Oxygen Gas Company, which was changed because of its diversification of products.